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ON THE GAMETOPHYTES AND EMBRYO OF TAXODIUM.[1]

CONTRIBUTIONS FROM THE BOTANICAL LABORATORY OF THE JOHNS HOPKINS UNIVERSITY, No. 1.

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(WITH PLATES I–XI)

In spite of the recent great increase in our knowledge of spermatogenesis in many groups of gymnosperms, this part of the life history of the Taxodieae remained, at the time this work was undertaken, almost unknown. A short contribution by Shaw ('97) on Sequoia had appeared in 1897, and Arnoldi ('99[a, b]) has recently added two papers on the development of the reproductive organs in Sequoia. These observers have cleared up many salient points in the development of this genus, but the group as a whole is still to be studied.

Taxodium itself, probably on account of its limited geographical distribution, has been greatly neglected by investigators. Coulter on the histology of the leaf, Masters on the seedling, Lotsy and Meehan on the knees, and Von Schrenk on the disease called "peckiness" are among the few papers that have been devoted, in whole or in part, to the study of Taxodium, and none is concerned with the development of the seed.

The present work was suggested by Dr. D. S. Johnson, to whom I wish to express my gratitude for his unfailing kindness and helpful advice throughout its prosecution. I also wish

[1] A dissertation submitted to the Board of University Studies of the Johns Hopkins University, June 1901, for the degree of Doctor of Philosophy.

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publicly to thank my brothers for their assistance in sending me material at frequent intervals.

METHODS.

Collections of *Taxodium distichum* Richard, the only species studied, have been made for about three years, chiefly from Hartsville, S. C., but also from Baltimore, Md., and New Berne, N. C. Fixing has been done at the tree in all critical stages, but fresh material, sent in tight boxes from Hartsville to Baltimore, has frequently given good results. Flemming's strong solution, chrom-acetic acid solution, alcoholic solution of picric acid, saturated solution of corrosive sublimate in 95 per cent. alcohol have all been used to some extent; but a saturated aqueous solution of corrosive sublimate (95 or 90 parts) and glacial acetic acid (5 or 10 parts) has been generally used. The latter gives results that are scarcely, if at all, inferior to those obtained with the Flemming solution, while it is more satisfactory than any of the other fluids mentioned. In searching for protoplasmic connections between cells, Gardner's ('83) methods were used, but only with fixed material. Potassium iodid and chlor-zinc-iodid were useful in determining the presence of starch, and have been used throughout for this purpose. A number of stains have been tried, but Flemming's triple has been most used. Young cones were split, or the scales removed entire. In older cones the ovule was removed and the nucellus exposed by breaking off the lignified tip of the integument, or the whole prothallium was taken from the seed. Sections 5–10 μ thick were made by the usual paraffin method.

THE STAMINATE CONE.

The staminate flowers are born on short branches which are either simple or compound. If simple, these branches are usually longer and more numerous than if compound. They appear in the fall from near the tips of the branches of the same year, and at the beginning of October or even earlier the young staminate flowers may be seen in the axils of their scale-like leaves. A longitudinal section of a sporophyll at this time shows no distinction between primary archesporium and other

tissue, all the cells of the lower part of the sporophyll being of about the same size, and having dense contents. Soon, however, certain centrally placed hypodermal cells begin to divide by periclinal walls and give rise to rows of cells as shown in *fig. 1*. The outermost cells of these rows, by a periclinal division, form the one-layered tapetum and the inner layer of the sporangial wall. By division of adjoining cells the tapetal layer is extended completely around the sporogenous tissue (*fig. 2*), and by January, or earlier, the microspore mother-cells are formed and ready for their division in early spring. Chamberlain ('98) has reported a similar stage during winter in the microsporangia of Pinus, Cupressus, and Taxus. The cells of the whole sporophyll, with the exception of the tapetum and the sporogenous tissue, contain starch through the late fall and winter until renewed growth in spring alters its arrangement. In the middle of November the nuclei of the tapetal layer show a peculiar structure not found at other times. They have a very coarse and wide-meshed reticulum, upon which the chromatin is distributed in large granules of very unequal size. There is no nucleolus. The nuclei of the sporogenous tissue have several nucleoli and a thinner reticulum than at a later stage.

No trace of an indusium-like outgrowth from the sporophyll is present for the protection of the sporangia, such as occurs in Cupressus, Thuja, and species of Juniperus. During early stages of development the cells of the upper part of the sporophyll are completely filled with a peculiar homogeneous substance staining bluish with gentian, which, as its subsequent history shows, is either a form of starch or an intermediate product in the formation of starch. It is not stained blue by iodin. At the stage of *fig. 1*, this substance is being replaced by starch grains of the usual kind, and a direct relation in amount between the two is evident, the starch appearing in proportion as the amorphous substance disappears. The cells on the line of transformation contain both starch and amorphous substances in proportionately smaller quantities.

Before their division in the spring, the pollen mother-cells become filled with starch, while the grains in other parts of the

sporophyll are being rapidly corroded. The persistence of this starch in the mother-cells during division and its disappearance as the exine is formed in the pollen grain agrees with what is already known in cycads and conifers. The ripe pollen grain contains no starch, nor is any found in the pollen tube until it appears in the protoplasm of the central cell shortly before the formation of the sperm cells. The number of microsporangia on a sporophyll may be as many as nine, seven being a common number. The wall of the mature microsporangium consists of but two layers of cells on the exposed surface, and in this respect Taxodium differs from the Abieteae, Taxeae, Cycadales, and Ginkgo, and agrees with the Cupresseae and Gnetales. The cells of the outer layer of the wall have the sides and inner faces strengthened by bands of cellulose, while those of the inner layer are very much flattened and poor in contents. The cells in the tapetum have very dense contents and are shorter and thicker than those of the inner wall. They disorganize at about the time that the division occurs in the pollen grains.

The division of the pollen mother-cells took place this year (1901) in South Carolina on March 6th, and both divisions were found on the same day, even in the same cone, but the stages found in the same sporangium are not quite so different as Coulter and Chamberlain ('01) figure for *Pinus Laricio*. Changes of the nucleus leading up to the first division were not present in my material, but good preparations of all stages during and subsequent to the metaphase of the first division show that the phenomena are similar in all essential respects to those described in detail by Strasburger ('00) for Larix.

The chromosomes, as arranged on the nuclear plate, are short and thick (*fig. 3*). They stand at right angles to the axis of the spindle, the fibers being attached to the inner ends. The splitting begins at the point of attachment and in favorable cases the line may be seen between the two halves in the as yet unseparated outer limb. Very soon after the splitting is completed and the daughter chromosomes begin to move to the poles, the fibers are seen to be attached to the middle of the

bent chromosomes and the inner ends of the latter are composed of four arms, lying side by side, and generally of the same length (*figs. 4–6*). The second splitting has evidently occurred and the arrangement is now just as in Larix as described by Strasburger ('00). The chromosomes remain thick and short as they approach the poles, and their number can be easily determined to be either eleven or twelve. Eleven are shown in *fig. 6* in polar view, and at least this number could be distinctly made out in other cases. Sometimes there seem to be twelve, but on account of the crowding in such cases I have never been sure of this number. Twelve chromosomes have been found by Belajeff ('94) and Strasburger ('92) in the pollen mother-cells of *Larix europaea*, by Blackmann ('98) in pollen mother-cells and oosphere of *Pinus sylvestris*, by Juel ('00) in the megaspore mother-cell of *Larix sibirica*, and by Chamberlain ('99) in the pollen mother-cells, endosperm, and jacket cells of *Pinis laricio*. It would thus seem from analogy that the number of chromosomes in the pollen mother-cells of Taxodium is also twelve rather than eleven.

The daughter nuclei (*fig. 7*) before the next division enter into a fairly well-developed resting stage. There is a distinct reticulum, if indeed a rather coarse one, and the chromatin is grouped in larger masses than in the reticulum of many resting cells, approaching more nearly the condition already described in the nuclei of the tapetal layer of the microsporangium in November. Strasburger ('00) describes such a condition in Larix, but tries to bring it in harmony with other cases by considering the network as spun out from the chromosomes. His distinction is not clear to me, and I think it must be acknowledged that the daughter nuclei of the first division may, at least in some cases, reach before their next division a relatively well advanced resting stage. From *fig. 7* it will be seen that the cell walls of the mother-cell have not disappeared at the time of tetrad-formation. In places the walls have begun to go to pieces, but in others remain entire and in close contact with their neighbors. No case was found where the final divisions were bilateral, as is sometimes the case in *Pinus Laricio* (Coulter and Chamberlain, '01).

The connecting fibers of the first spindle produce a distinct cell-plate, extending entirely across the cell before the nuclei have begun to divide a second time. On each side of the plate the starch grains are densely crowded. The chromosomes of the second division are single slightly curved rods, and are evidently of about the same size as the halves of the double chromosomes of the first division. The starch begins to disappear during the second division of the pollen mother-cell, and is completely used up during the formation of the exine of the pollen grains, which becomes quite evident in about three days after the last division. The nucleus of the fully formed but yet undivided pollen grain is evenly and coarsely granular and generally without a nucleolus (*fig. 8*).

About ten days after its formation the pollen grain divides. The spindle is very small and the chromosomes are proportionately longer than in the reducing division (*figs. 9* and *10*). This is the only division of the pollen grain, no sterile prothallial cell being formed, and it separates at once the generative cell from the tube cell. The former is flattened lens-shaped, concave toward the inside, and furnished with a distinct *Hautschicht* (*fig. 11*). This division occurs a few days before the pollen is shed, and it is in this condition that the ripe pollen reaches the nucellus (*fig. 12*). In the absence of any sterile prothallial cells, Taxodium agrees with the Cupresseae and Taxus, and differs from all other conifers and cycads. The number of sterile prothallial cells in the pollen grain of gymnosperms has been determined in the following cases: two in Ginkgo (Strasburger, '92), *Larix europaea* (Strasburger, '84), *Picea vulgaris* (Belajeff, '93), *Pinus silvestris* (Strasburger, '92), *Pinus Pumilio* (Coulter and Chamberlain, '01); one in Ceratozamia (Juranyi, '82; he occasionally found two in *C. longifolia*), Zamia (Webber, '97), Cycas (Ikeno, '99); none in Biota, Cupressus, Juniperus (Strasburger, '92), *Taxus baccata* and Juniperus (Belajeff, '93).

The great importance of correctly determining the number of divisions in the pollen grain has not been overlooked, and repeated sections, at all stages of the development of the pollen

from the mother-cell stage to the sprouting of the pollen tube, have been made from collections obtained in both 1900 and 1901, and I think it certain that there is but one division of the pollen cell in Taxodium.

THE POLLEN TUBE.

The first indication of sprouting is given by the swelling up of the generative cell into the tube cell, and by an increase in size of both nuclei (*fig. 13*). The exine is usually thrown off at an early stage, as shown in *fig. 14*. In this figure the nuclei of the pollen tube have not changed their position, the tube nucleus lying immediately above the generative cell. The pollen tube contains no starch, either now or during its course to the prothallium. As the tube advances, the tube nucleus moves from its position over the generative cell and passes slowly down toward the tip. Indications of branching are soon seen in the pollen tube (*figs. 17, 29, 22, 23*). In *fig. 16* the generative cell seems by its position to be bounded by an actual membrane, but no indication of a cellulose wall was obtained, and if one is present it is exceedingly thin and quickly dissolved. By comparing *figs. 15* and *16* it will be seen that the sprouting does not take place at any definite point in reference to the position of the generative cell.

The division of the generative cell does not occur until several weeks after the sprouting of the grain (*figs. 19–21*). The stalk nucleus soon loses its definite hold upon the protoplasm around it, although immediately after the division (*fig. 19*) it is still bounded by a distinct protoplasmic sheath. The central cell retains the characteristics which mark the generative cell before division. It is furnished with a distinct *Hautschicht* and has the shape of a double convex lens. It will be noticed that immediately after the division the stalk cell is larger than the central cell. Belajeff ('91, '93) describes these two cells as being of equal size in Taxus. In *Juniperus communis* he ('93) finds the outer cell to be smaller, while in *Picea vulgaris* the opposite is true. There is not much difference in size in *Pinus Laricio*, as figured by Coulter and Chamberlain ('91). It will thus be seen that Taxodium agrees with Juniperus in the relative size of the stalk and central cells immediately after their formation.

Belajeff ('91, '93) describes the stalk nucleus as passing the central cell as it wanders down the tube. Such a description could hardly be applied in Taxodium when the tube is at right angles to the axis of the spindle of the generative cell. The stalk nucleus is as near the tip of the tube as is the central cell, and they both wander down together until they reach the tube nucleus (*fig. 22*). It will be seen from *fig. 26* that the three nuclei of the pollen tube can easily be distinguished at this stage. The stalk nucleus is smaller than the tube nucleus, while the protoplasm of the central cell is distinct from that of the pollen tube. The stalk and tube nuclei now advance slightly ahead of the central cell (*fig. 23*), and this relative position is retained by the three nuclei throughout the subsequent history of the pollen tube. In *fig. 23* the stalk nucleus is still slightly smaller than the tube nucleus, but the structure of the two is the same. The male nucleus is very like the other two, its nucleolus being slightly smaller.

The pollen tube proceeds to the prothallium without interruption; the growth, however, is much slower in the upper part of the nucellus than in the lower. No particular tissue of the nucellus tip is set apart to nourish or guide the pollen tube. All of its cells contain more or less starch, but there is no grouping of starch in definite areas. The pollen tube may reach the megaspore before the formation of a cellular prothallium (*fig. 25*). So early an approach of the pollen tube to the sprouting megaspore has not been described in any other case, so far as I am aware. Jäger ('99) gives one figure of *Taxus baccata* showing a pollen tube almost in contact with a young prothallium, and I have found that in *Taxus baccata canadensis* the pollen tube may reach the level of the megaspore before the latter has divided even once. One case was found in this plant where the pollen tube has grown against and badly compressed the megaspore before the latter had advanced far beyond the sixteen-cell stage. It was so completely crushed that the stage could not be exactly determined.

Fig. 26 gives the structure of the contents of the pollen-tube at a slightly later stage than *fig. 25*. The two free nuclei are

now exactly similar and lie side by side immediately beneath the central cell. The latter has increased greatly in size, as has also its nucleus, and the protoplasm is seen to possess a radiate structure. We find in the nucleus of the central cell a distinct peripheral network, and a nucleolus, irregular in outline and evidently of a compound nature. This kind of nucleolus, which we here meet for the first time, will be found to occur also in the nucleus of the central cell of the archegonium. In one case the central cell was at the tip of the pollen tube, with the two free nuclei behind it. One of the latter was pressed so closely to the protoplasm of the central cell as to indent it slightly. Such an abnormal relation between the generative and free nuclei has been noted in *Pinus Laricio* by Coulter ('97).

The further changes in the central cell before its final division into the sperm cells are so remarkable and have been so neglected in other conifers studied that I shall go into them with some detail. *Fig. 27* represents the central cell after it has reached its full size. It is no longer spherical, but has become elliptical in section, the long axis being perpendicular to the axis of the tube. The protoplasm is seen to be radiating from the two poles of the long axis. At these poles are sometimes to be distinguished slightly more granular areas, from which the radiations seem to diverge. The protoplasm is very dense, finely granular and in thin sections can be seen to have a reticulate structure. The faint areas at the poles of the cells will at once suggest in position the blepharoplasts of Ginkgo, Zamia, and Cycas. In reality, the resemblance is entirely confined to their position. Dr. Webber has kindly shown me his preparations of blepharoplasts in Zamia, and their intense staining and large size make further comparison impossible.

The nucleus, which is about half of the diameter of the cell, has rather abundant reticulum and a fragmented nucleolus. In addition to these, there has appeared a finely granular material which does not seem to differ in any respect from the linin material in the egg nucleus to be described below. It is most abundant around the nucleolus, but extends to all parts of the nucleus. In *fig. 27* one of the free nuclei is seen closely appressed

to the *Hautschicht* of the central cell; the other free nucleus does not appear in the section. This is about the latest stage at which these free nuclei retain their normal structure. They very soon begin to go to pieces, and the protoplasm of the pollen tube at the same time begins to disorganize. It becomes more homogeneous and retains more tenaciously the safranin stain. The nucleoli and chromatin of the free nuclei become more or less broken up and collected into masses of different size, a process which we shall see corresponds exactly to what occurs in the nuclei of the jacket cells of the archegonium shortly before its final division. Concomitantly with the disorganization of the nuclei and cytoplasm of the pollen tube, there becomes evident in the cytoplasm of the central cell a number of bodies staining a deep red in safranin. They resemble exactly the plastin granules that we have seen to appear at the disorganization of the free nuclei, and that they are actually transferred from the latter into the central cell seems possible. *Fig. 28* is a central cell after the appearance of these granules. They are arranged in a circular manner at some distance from the nucleus, and it may be that this distribution is connected in some way with the concentric arrangement of the fibers. At the time of the appearance of the plastin granules in the protoplasm of the central cell, there seems to be a distinct connection at the base of the cell between its protoplasm and that of the disorganizing material beneath it. Hirase ('95) describes large bodies lying in the protoplasm of the central cell of Ginkgo between the nucleus and the blepharoplasts. Webber ('97) confirms this and says that in addition to the two large bodies smaller masses of similar material were observed in other localities of the cell. He speaks of them as extra-nuclear nuclein. It is easy to compare these bodies with those of Taxodium. They stain deeply with safranin in both cases, the principal difference being that in Ginkgo they are generally fused into two large masses which occupy a definite position in the cell.

The disorganized mass of nuclei and protoplasm at the tip of the tube never completely disappears before fertilization, and it may appear in the tip of the archegonium above the protoplasm

of the egg after fertilization. In *fig. 28* a number of scattered starch grains have made their appearance in the cytoplasm of the central cell. They retain their scattered position until finally arranged into the dense starch sheath immediately surrounding the nucleus of the sperm-cell.

Changes in the nucleus preparatory to the final division of the central cell had already begun at the stage represented in *fig. 27*. In *fig. 28* these changes have proceeded still further. The chromosomes are being prepared from the few thick conspicuous threads that are present. The linin granules have become organized into a reticulum, and this reticulum seems to be arranging itself as if in the preparatory stages of spindle formation.

No attempt was made to study in detail all stages of spindle formation in the division of the central cell, but in *fig. 29*, which shows an oblique view of the spindle, the formation of its fibers from the nuclear reticulum and the granular nature of the more peripheral fibers seems evident. This formation of the spindle from the fibers of the nucleus will be described in more detail in the division of the ventral canal cell. *Fig. 30* shows a late telophase in the division of the central cell, the connecting fibers still being evident. A clear area is noticed on each side of the cell plate, and this area later extends entirely around the sperm cells. The starch and plastin material are collected at the distal ends of the spindle, but after the separation of the two daughter cells the starch becomes arranged in a dense sheath immediately surrounding the nucleus (*fig. 31*). Just outside of this sheath the plastin granules form a more or less complete layer. Beyond them is found the clear area previously mentioned, and the surface is composed of a distinct membrane which sharply defines the sperm cells from the protoplasm of the tube. After the formation of the daughter nuclei, they again begin to fill with the linin granules or reticulum (the so-called metaplasmic substance of Strasburger) until, at the time of maturity, they are so dense as to make any distinction between the granular material and chromatin reticulum very difficult. A small nucleolus, however, can be dimly discerned (*fig. 31*).

The sperm cells are now mature, and fertilization almost immediately takes place. I think it probable that the sperm cells do not round themselves off completely until after the bursting of the pollen tube, for although sometimes separated as much as a quarter of their diameter from each other, I have never seen them while still in the tube without a flat face on the inner side. This remarkably complex structure of the sperm cell distinguishes Taxodium from any phanerogam hitherto described, with the exception of Ginkgo and the cycads.

Recent work on the conifers, which in the structure of the male gametophyte approach Taxodium, gives very little detail as to the structure of the sperm cells. In Taxus Jäger ('99) mentions radial striae in the periphery of both the sperm cell and its smaller, functionless sister cell, but gives no further details of the protoplasmic structure. Arnoldi ('98) says that in Cephalotaxus the protoplasm of the sperm cells, which are here of equal size, is densest around the nucleus. In his work on Sequoia ('99) he gives no details of the protoplasmic structure of the sperm cells, but says they resemble those of the Cupresseae. Blackman ('98) makes some interesting observations on the sperm cells of *Pinus silvestris*. He says: "It cannot be doubted that cytoplasm also passes over into the oosphere, for each generative nucleus in the pollen tube is clearly surrounded by its own layer of cytoplasm, as can be observed in the stage when the tube is already in contact with the oosphere." Also, "it may here be noticed that small bodies staining deeply with fuchsin S may be observed in the generative cell protoplasm." These, he says, resemble leucoplasts. "If leucoplasts are really present in the cytoplasm belonging to the generative cells, the general view that the male cell brings over no plastids to the egg appears to be directly contradicted." This is the only mention I have seen made of a distinctive protoplasm belonging to the male cells in any of the Abieteae.

Neither Belajeff ('91, '93) nor Strasburger ('79, '84) describe the structure of the sperm cells of the Cupresseae in detail, but in gross structure they seem almost identical with those of Taxodium. Strasburger ('84) says that the pollen tube of Juni-

perus contains very little starch at time of fertilization, and thinks it therefore the more remarkable that the fusion nucleus should be surrounded by so much starch. From comparison with Taxodium, however, it seems probable that starch is also present in the sperm cells of the Cupresseae and has heretofore been overlooked. We shall see that a comparison of the processes of fertilization in the two cases strengthens this view.

The tip of the pollen tube has not been found to possess a distinct pit, such as is described by Goroschankin ('83), Dixon ('94), and Blackman ('98) in other conifers. The whole tip of the tube is furnished with a thinner cell wall than is found above, and if any pit occurs it is rendered less conspicuous by the thinness of the adjoining wall.

G.S.L.

THE OVULATE CONE.

In October of the year preceding the ripening of the seed, the ovulate cones of Taxodium appear as very inconspicuous axillary buds on shoots of the same year. They usually occupy positions near the tip of the branch, and vary greatly in the number formed. It has usually been said that the ovulate cones are borne two or three together at the tip of branches which have also produced, further down, branches of the staminate inflorescence. While this is sometimes the case, and frequently so in trees examined in Baltimore, in its more natural habitat the ovulate cones are situated on branches of their own, and occur in much greater numbers than described. As many as fifteen or twenty mature cones have been found closely crowded on a fertile branch, and while this is the exception, as many as eight or ten are frequently grouped on vigorous trees. The ovulate cones replace the dehiscent short branches. The latter do not appear in the axils of all the scale leaves during the first year, but in only about one-third of them. The next year they are found in axils of leaves which were not occupied the previous year, but in following years they come from supernumerary axillary buds, and in the more slowly growing parts of the tree may appear year after year in the axil of the same scale leaf.

Fig. 32 shows a megasporophyll collected October 3, 1899.

In the axil of the sporophyll two swellings are present, the section passing longitudinally through one of them. These are the rudiments of the ovules which by January 4 (*fig. 33*) have begun to show the first indication of an integument. *Fig. 34* shows a sporophyll collected in Baltimore March 11. The ovule has increased in size and the nucellus and integument are of equal height. It seems that slow growth is continued all through the winter months whenever the condition of the weather will permit. A few weeks before the time of pollination, the placental outgrowth begins to appear as slight projections between and at the sides of the sporangia. By April 8 (*fig. 36*) the cushion has begun to show between ovule and scale, and by April 22 (*fig. 37*) it has reached a considerable size. The further development of the sporophyll is almost entirely confined to its basal part where cushion and scale are indistinguishable, and to the great extension of the cushion above and sidewise as a protective covering to the ovules. The tip above the cushion remains small and is soon much surpassed by the latter, which by fusing with the scale above soon comes to inclose completely the cavity in which the ovules lie. The outgrowths are not confined to the ovule-bearing scales, but are developed in almost as great degree in the axils of the adjoining scales below and at the tip. The number of fertile scales is usually about ten. They are bounded beneath and above by scales differing from them only in the absence of ovules. As the growth proceeds, the area of attachment of the ovules to the scale becomes much greater in extent, so that when the seed is mature almost the whole of its outer face is attached to the inner face of the scale.

This is not the place for a discussion of the homologies of the so-called placental cushion, and I shall confine myself to the expression of my belief that it is a new formation for the purpose of closing the opening between the scales for the protection of the ovules, and is not derived either from fused leaves or from a second integument of the ovule.

At the time of pollination the tip of the integument is composed of about three layers of cells, but immediately after pol-

lination the inner cells near the tip begin to grow in at certain points, and approaching the center almost completely close the micropylar cavity (*fig. 37*). There soon begins to appear in the tip of the integument an irregular ring of lignified cells with thick and pitted walls, which serves to strengthen this exposed end (*fig. 49*).

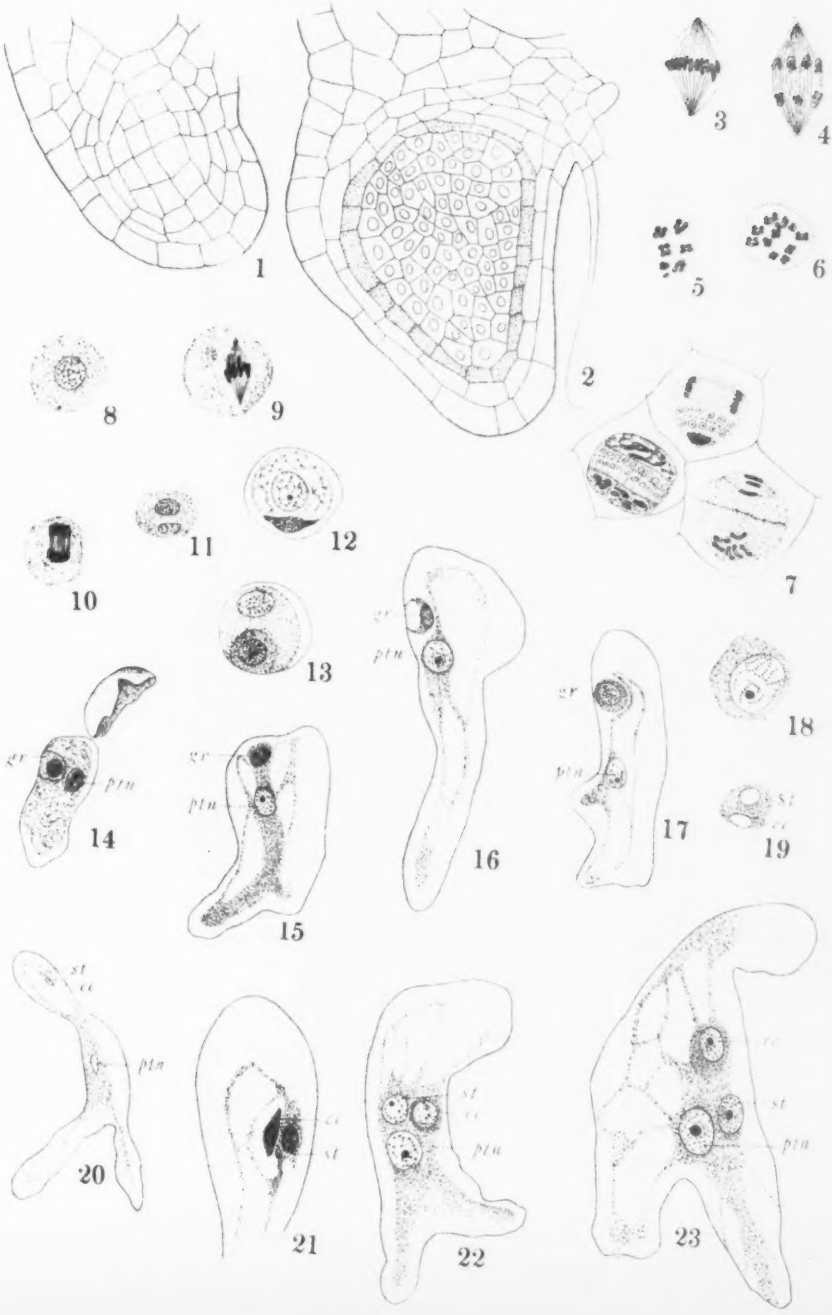
THE MEGASPORE.

The megaspore mother-cell cannot be distinguished from its neighbors until shortly before pollination. It is the basal or next to the basal cell of one of the distinct cell-rows which are evident in the center of the nucellus, and is situated at the same level as the point of insertion of the integument (*figs. 35, 37*). In this respect Taxodium agrees with the Cupresseae and differs markedly from Sequoia (Shaw, '96). At the time of pollination the megaspore mother-cell is slightly larger than the cells immediately surrounding it. Only a single megaspore mother-cell is present at this stage, but one case was found (*fig. 50*) in which the nucellus contained two young prothallia, one of which was larger than the other. Whether these were derived from two mother-cells or from the same mother-cell is a matter of conjecture. In this respect also Taxodium is seen to differ from Sequoia, in which Shaw ('96) and Arnoldi ('99[b]) have found it the rule for a number of prothallia to be developed. Hofmeister ('51) mentions the occasional presence of two prothallia in *Pinus silvestris* and *Taxus baccata* (confirmed since by Farmer ['92] for Pinus and by Jäger for Taxus), and I have found two in Podocarpus and *Taxus baccata canadensis*. With these exceptions the development of more than one prothallium has not been observed in the conifers.

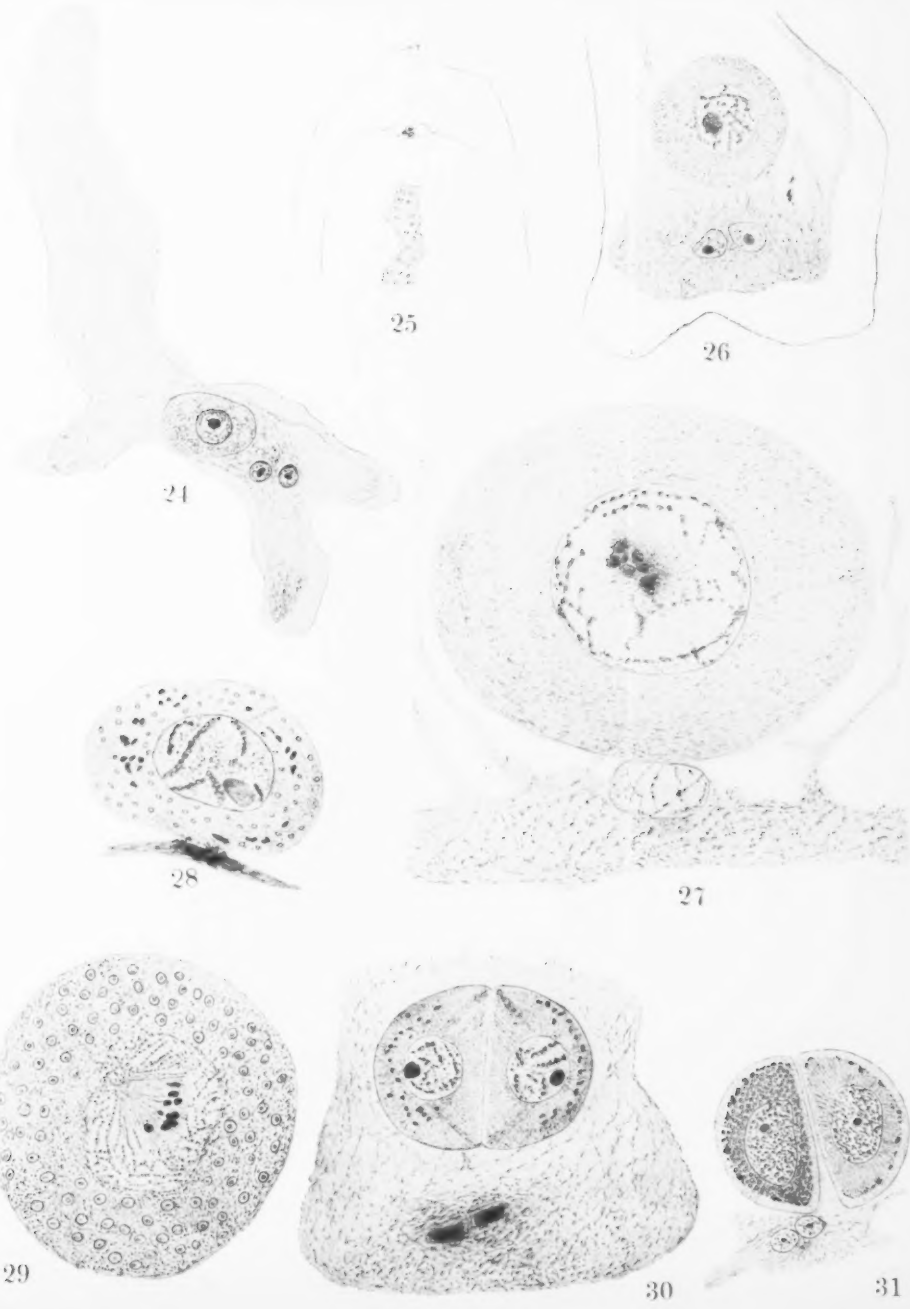
The mother-cell increases slowly in size after pollination, and in about ten days the first division occurs. *Fig. 39* is a mother-cell shortly before its first division. It is abundantly supplied with starch grains, as are also the adjoining cells for about one layer. It will be seen that the nucleus is in synapsis, the meshwork being in a contracted mass near the nucleolus. Such a synapsis is found by Juel ('00) at the same stage in *Larix sibirica*. He also mentions the presence of denser fibrous areas at

either end of the cell near the nucleus. These areas are frequently to be noticed in the megaspore of Taxodium, but I have not been able to establish any definite relation between them and the spindle-formation (*figs. 38–43*). A slightly younger stage is shown in *fig. 38*, where the nucleus is of the usual structure and has not approached the tip of the cell, in which position it is always to be found before the first division. Stages of the first division are shown in *figs. 40–42*. The chromosomes were not counted, but are evidently not far from twelve in number. This division cuts off a large lower cell and a much smaller upper cell. The lower cell immediately prepares to divide again. The second spindle is shown in *fig. 43*, and in *fig. 44* the division is complete. The starch has begun to disappear during these divisions, but some is present until the conclusion of the second. Strasburger ('79) describes it as disappearing in *Larix europaea* before the second division; the same is true in *L. sibirica* (Juel, '01) and *Pinus Pumilio* (Coulter and Chamberlain, '01).

The upper of the two cells formed at the first division does not divide again, and its nucleus never reaches the resting stage, or indeed approaches it. *Fig. 42* shows the difference in the nuclei of the upper and lower cells of the first division. The lower is developing as usual, but the upper has formed no reticulum, and in fact never reaches a more highly organized stage. Its chromosomes remain fused and lumped, and soon present merely a disorganized, homogeneous appearance. This history of the upper nucleus is repeated in detail by that of the upper cell of the second division. There are thus formed in Taxodium only three cells from the division of the megaspore mother-cell, but as the lower divides twice, it is in every respect the equivalent of a pollen grain, as much so as if the upper cell of the first division had divided, as is the case according to Juel ('00) in *Abies sibirica*. Strasburger ('79) gives three, or seldom more, as the number of potential megaspores derived from the mother-cell in Taxus. He also gives the same number in *Larix europaea*, but as Juel has found four in *L. sibirica* it is possible that Strasburger may have overlooked one in *L. europaea*. Coulter and



COKER on TAXODIUM.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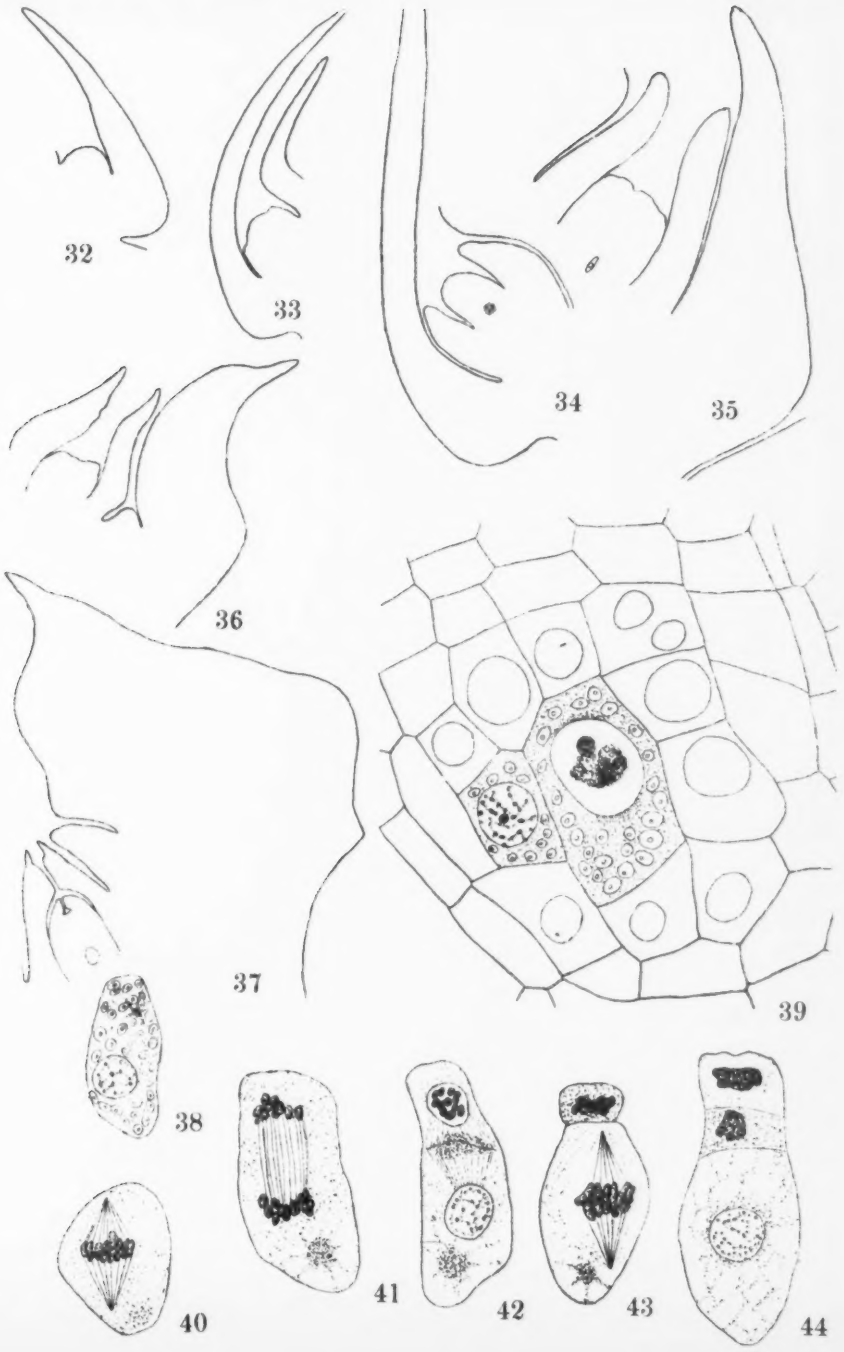

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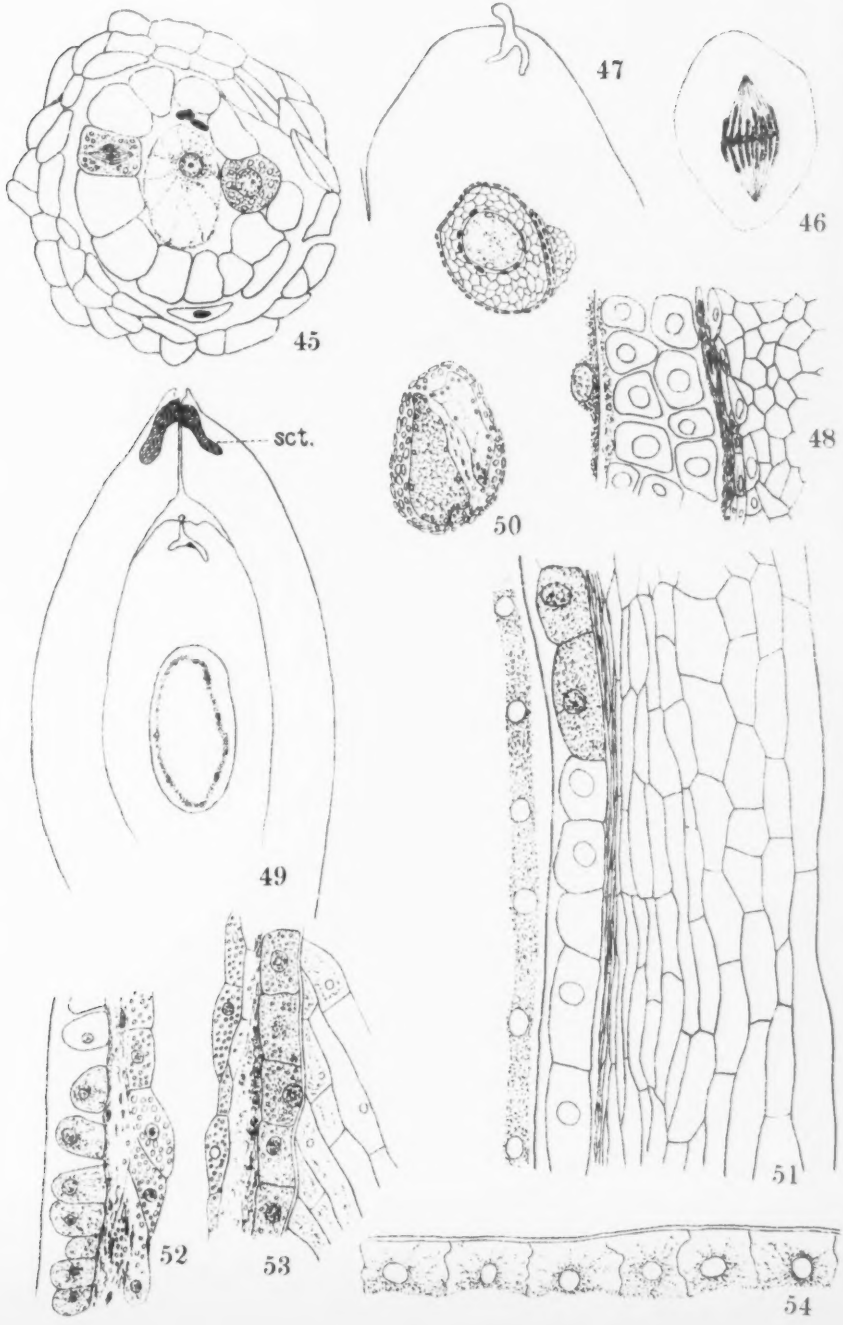

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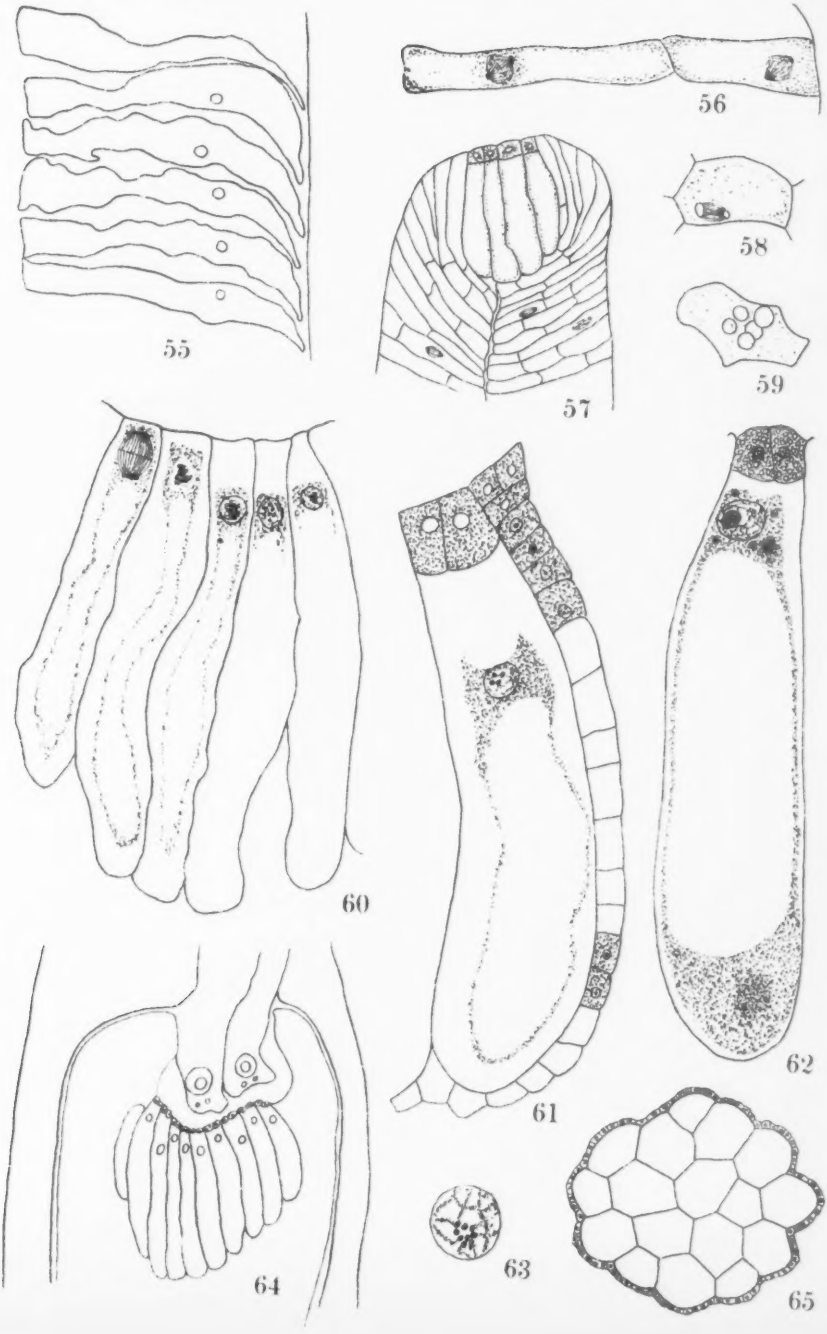

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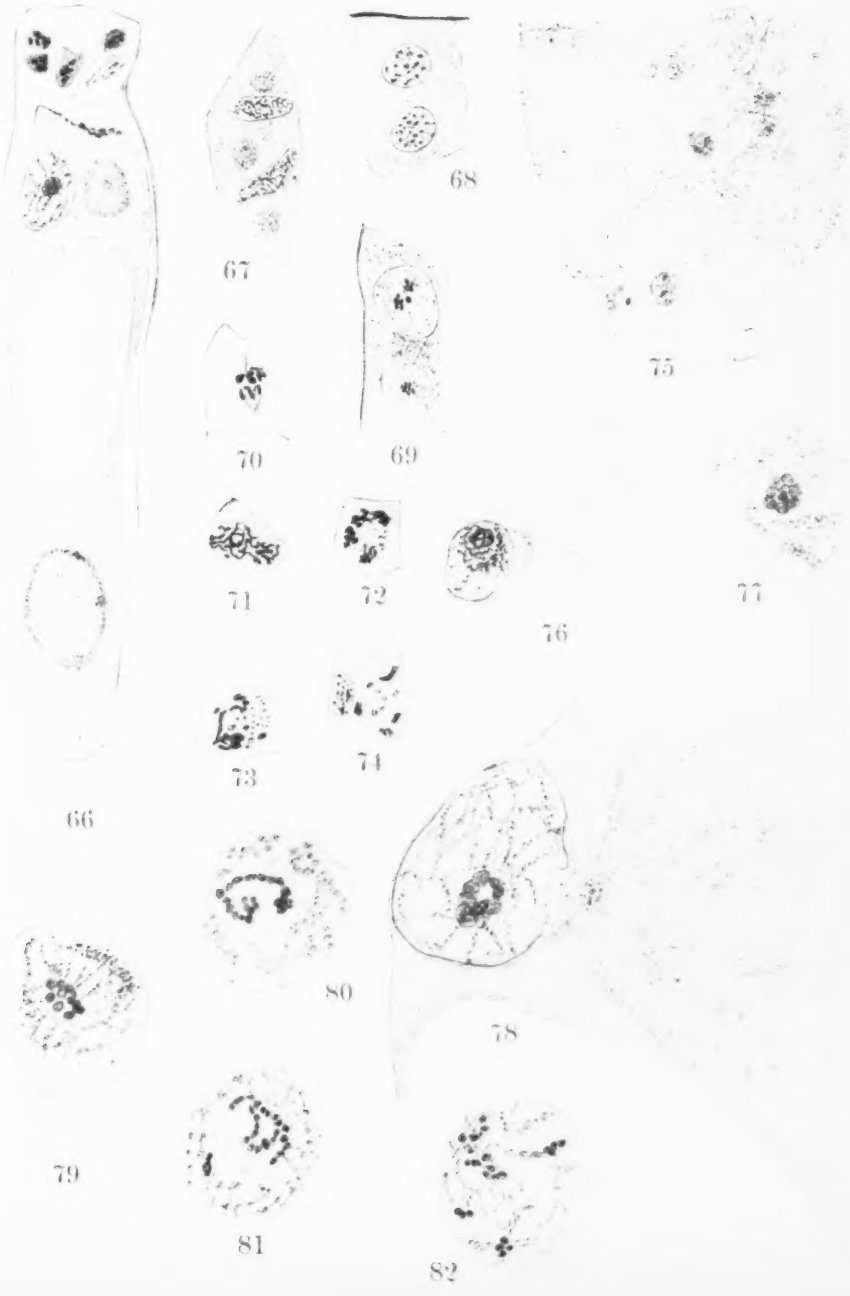
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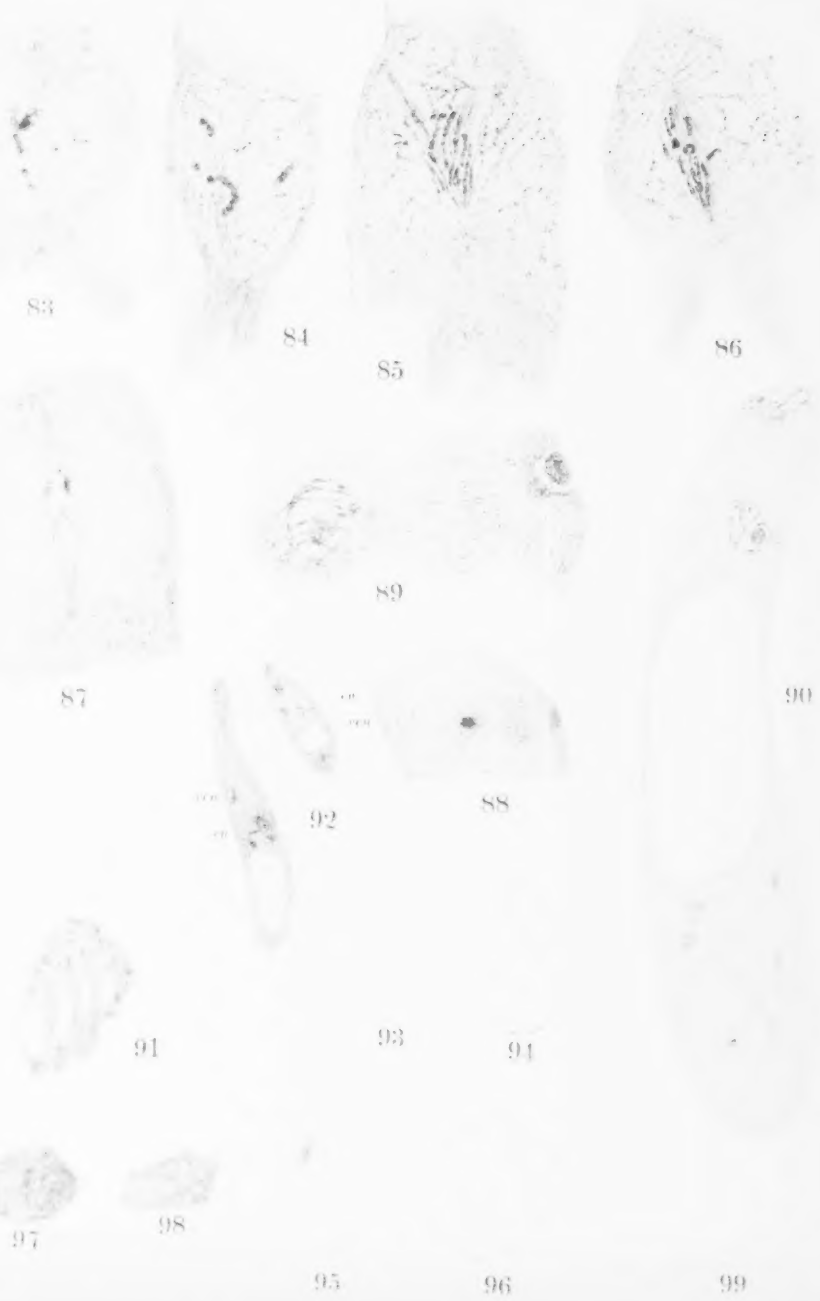
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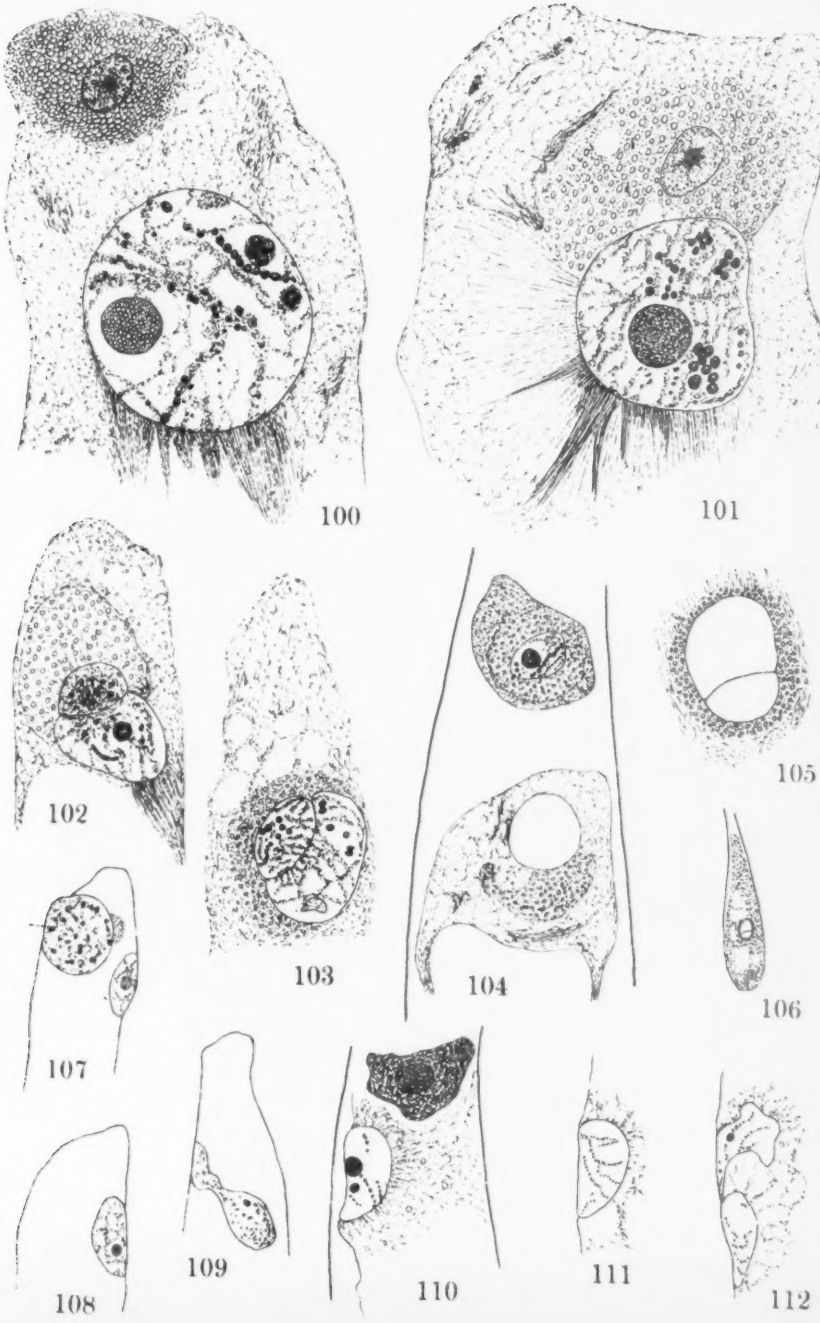

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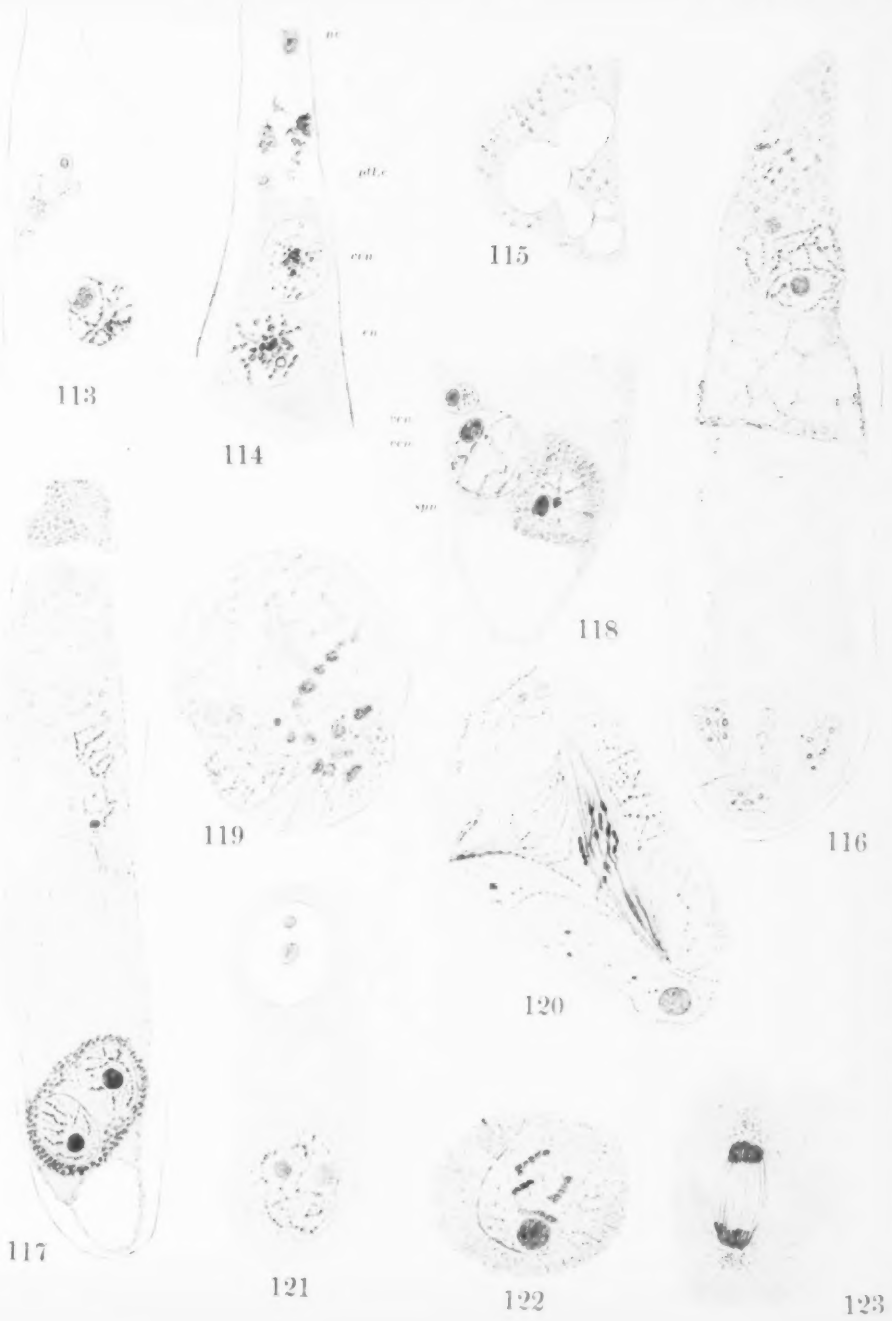
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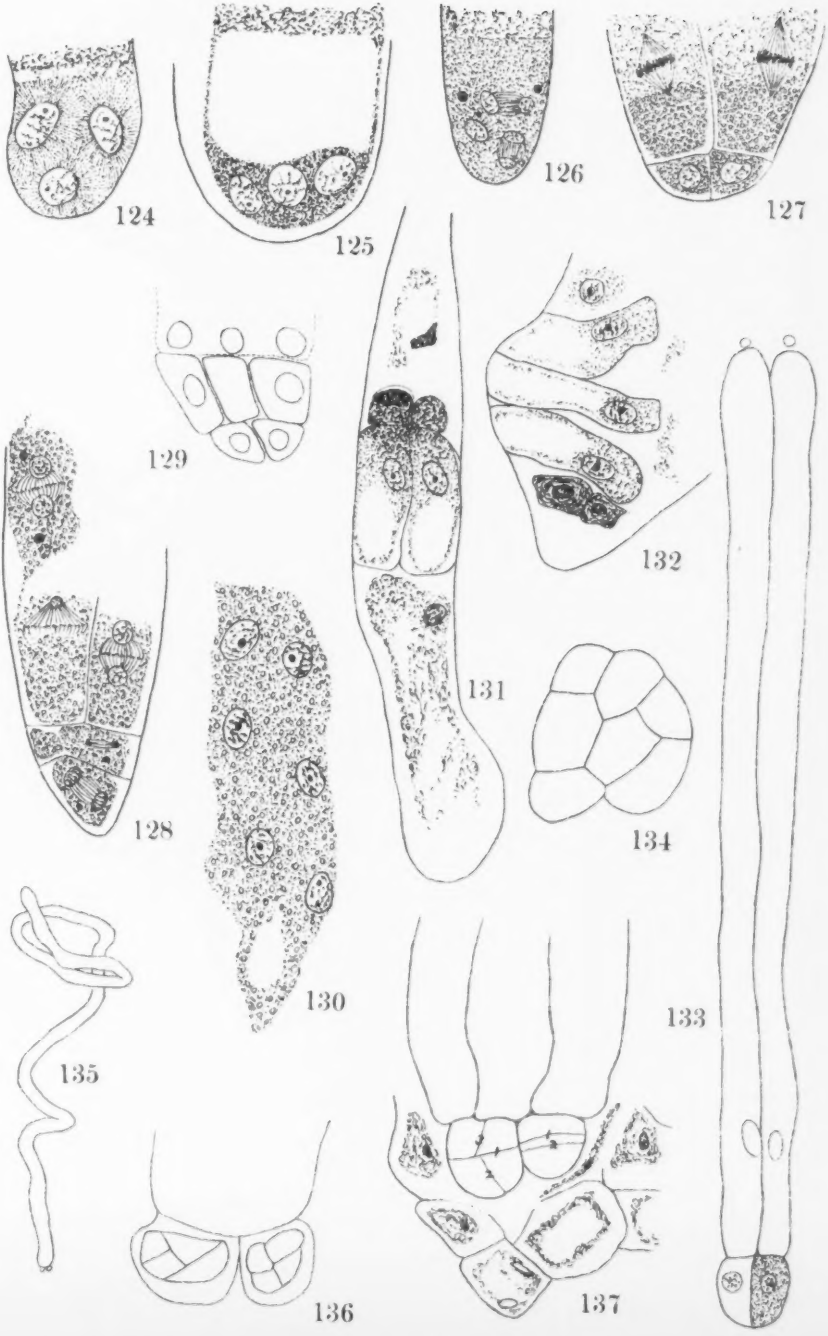

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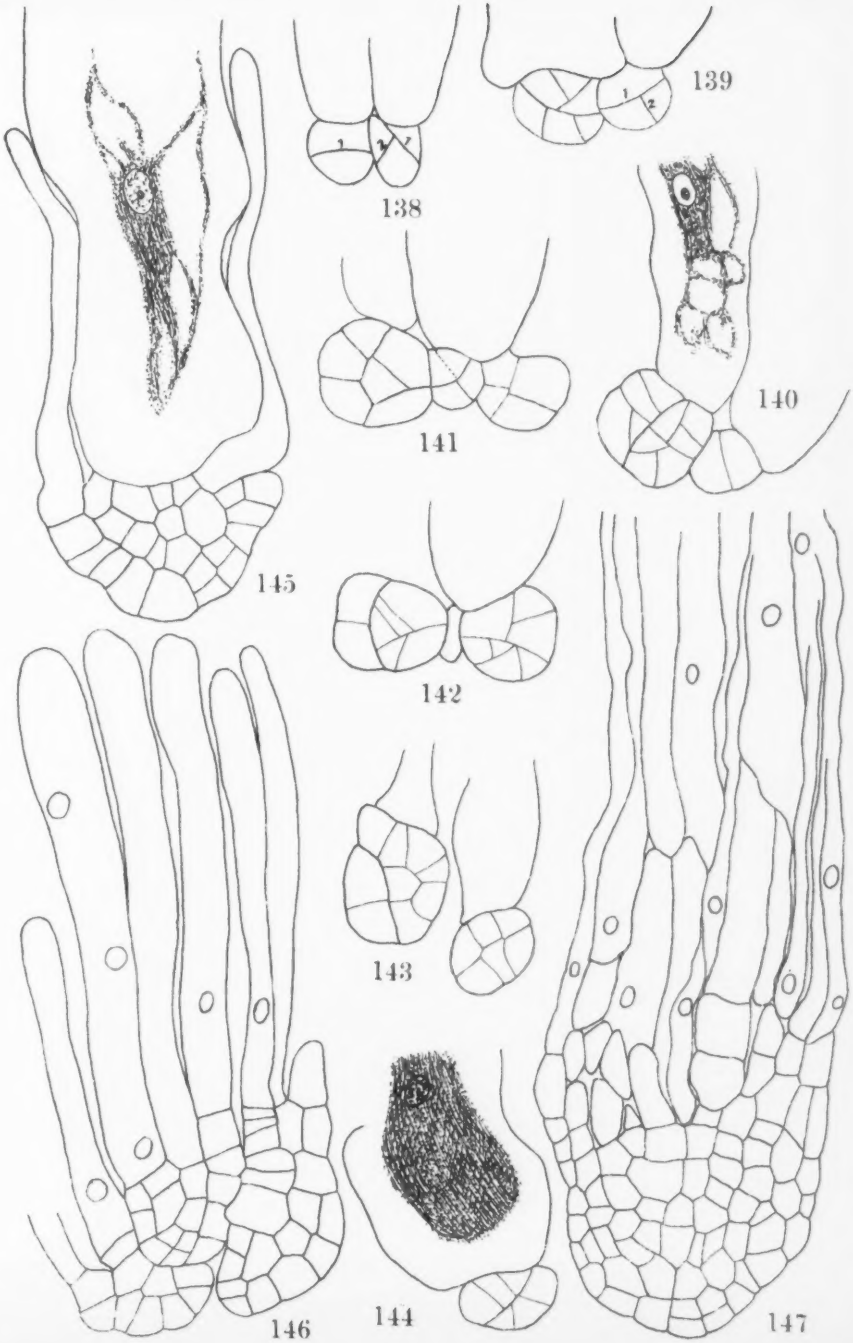

COKER on TAXODIUM.

Chamberlain ('01) also report four potential megaspores in *Pinus Laricio*, and Shaw ('96) has given the number as four in Sequoia. Almost nothing is known of the divisions of the megaspore mother-cell in the Cupresseae beyond Strasburger's remark that in Thuja the origin of the prothallium is essentially as in Taxus.

THE LARGE-CELLED TISSUE OR TAPETUM.

The cells immediately adjoining the megaspore mother-cell, as before stated, contain starch (*fig. 39*). After the megaspore is formed and begins to increase in size, the number of these dense, starch-containing, much enlarged cells is found to be greater (*fig. 45*). In *fig. 39* the transition between the starch-containing cells and the ordinary tissue around them is not very abrupt, but in *fig. 45* the boundary between the two has become distinctly marked. The larger cells are in close contact, their cell walls are intact, and their nuclei are large and apparently perfectly normal. Indeed, one of them is dividing mitotically, and they are not infrequently found dividing at this stage. *Fig. 46* shows such a cell in division. The spindle is placed centrally in the cell — not at one end, as in the division of the spore mother-cell — and in one case a cell-plate is being formed. The chromosomes were not counted, but the number is much more than twelve. The division seems to be an ordinary typical one. The cells immediately beyond the large-celled tissues are distinctly flattened and seem to be crushed by the cells within. On the lower side the nuclei of the nucellar tissue are frequently small, deeply stained in safranin, and apparently going to pieces. In one case at about this stage the nuclei in this position had entirely disappeared for a distance of several layers beyond the normal large-celled tissue. *Fig. 47* shows the large-celled tissue at a later stage. It has increased greatly in amount and the cells, which are now slightly separated from each other, are much more numerous. They retain the characters mentioned above for a younger stage.

The nucellar cells bordering on this tissue now show unmistakable signs of disorganization. They are completely crushed and broken up and are as strongly distinct from the large-celled

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tissue as the latter is from the megaspore. *Fig. 48* is a more magnified section of the same spore and tissue. A small amount of granular material appears between the spore and the large-celled tissue, but the inner walls of the latter are apparently intact. A few cases were found, however, where the innermost of the large cells seemed to be partly broken up on the side next the spore. At the stage shown in *fig. 49* the existence of so definite a layer around the spore is doubtful. The cells adjoining the spore are still larger than others beyond them, but in all cases that I have found they are more or less separated from each other and approach in appearance the loosened "spongy tissue" which has been described in other cases. In later stages, however, there constantly occurs a single layer of very large rectangular cells lying next to the megaspore, while beyond those the ordinary nucellus-tissue is crushed and disorganized. *Fig. 51* shows such a layer around a large spore before the formation of the cellular prothallium. The large cells seem perfectly intact; walls are present on both sides and the nucleus is large, has an abundant reticulum, and is more like what would be expected in an actively secreting cell than in a rapidly disorganizing one. *Figs. 52* and *53* show the same layer at a later stage, just before the prothallium has reached its full size. In *fig. 52* the wall of the megaspore has shrunken somewhat and the large cells have become more elongated and slightly separated. The layer of large cells and two or three layers of ordinary cells beyond it are always furnished with starch during the growth of the prothallium; the starch is continually accumulating in the further-removed cells as the inner ones are being disorganized. The large-celled layer is also destroyed at the last moment and the mature prothallium is surrounded at its upper end with four or five layers of ordinary nucellar cells. In the Abieteae the young germinating megaspore is imbedded in a loose tissue which resembles somewhat the large-celled tissue just described in Taxodium. Its limits are so distinct that Hofmeister ('62) mistook it for endosperm. In comparing Strasburger's ('79) figures of such tissue in Pinus and Larix with my *figs. 45* and *47* in Taxodium, it will be seen

that there is a great difference in structure in the two cases. Moreover, this tissue in the Abieteae is always spoken of as disorganizing. Coulter and Chamberlain ('01) have an interesting paragraph on this subject. They say: "In our figure of a mother-cell of *Pinus Laricio* imbedded in nucellar tissue, it is apparent that it is surrounded by a rather definite zone of cells, two to four layers in depth, which give evidence of breaking down. After endosperm-formation is somewhat advanced, this interesting zone becomes differentiated into two distinct regions, an outer layer of tabular, almost empty, cells, and an inner region of polygonal cells with densely staining contents." I do not know of any case, however, where this layer is said to persist in later stages. Strasburger ('79) describes a zone of more or less disorganized cells around the germinating megaspore of Thuja. I have examined growing sacs of Pinus, Larix, Thuja, Podocarpus, and Taxus in reference to this point. At the base of the prothallium in Podocarpus and around the very young germinating megaspore of Thuja there are cells which approach, in appearance, those found in Taxodium. In fact, there are frequently present around growing prothallia a number of swollen free cells, which might be compared to such a tissue as I have described in Taxodium, but in most cases these cells are not in close contact with one another and their development can be gradually traced from the ordinary cells of the nucellus. But I have not studied any of these plants carefully enough to deny the persistence in them of this tissue, and further observation is necessary to decide the matter.

It is difficult to understand the constant occurrence of a definite layer of large, distinctive, undisorganized cells around the growing prothallium in Taxodium, unless we ascribe to them an active part in the nourishment of the young gametophyte, and this I believe to be their real function. If this interpretation is the correct one, the tissue in question may be considered as a tapetum, which, instead of disorganizing at the maturity of the spore, as is usually the case, has continued its growth to keep pace with the developing prothallium which it continues to nourish until mature. If we consider the archesporium as

reduced to a single cell (the megaspore mother-cell), the tissue immediately around this cell must be considered as a tapetum, and we have seen that it is probably by the division of this tissue that the nourishing layer is formed. This cannot as yet be positively asserted for the later stages, as all steps have not been followed. The only other interpretation that seems possible is that the cells immediately surrounding the megaspore represent an originally archesporial tissue which has given up its function of spore-production and taken up the new rôle of nourishing the young plant within. Of these two interpretations I consider the first as much the more likely.

It is well known that the tapetum in the megasporangium of Selaginella persists intact until some time after the sprouting of the spores, which in this case are shed only after a considerable growth has occurred. Should the spores not be shed at all, and the tapetum continue still further its growth and function, we would have a condition paralleling that found in Taxodium.

DEVELOPMENT OF THE PROTHALLIUM.

We have left the megaspore to follow the surrounding tissue through its subsequent stages. The growth of the germinating megaspore is extremely slow during the first month after its formation, having reached on April 29 only about the 32-celled stage (*fig.* 47). Growth now becomes more rapid, and on May 6 it has reached the stage shown in *fig.* 49. About the beginning of June growth has stopped in the upper part and the formation of cell walls begins. *Fig.* 25 shows a stage just before the beginning of cell-formation. The pollen tube has already reached the megaspore, which now contains an enormous vacuole surrounded by a protoplasmic layer containing nuclei. In this case the protoplasmic layer has collapsed.

The great size reached by the germinating megaspore before the formation of cellular tissue seems to distinguish Taxodium from other conifers thus far studied. The wall of the spore was found to be furnished with pits. *Figs.* 97 and 98 show those pits in surface view at a time shortly before the formation of a cellular prothallium. The manner of the formation of the

first cell walls in the young gametophyte is shown in *fig. 24*, and I can confirm Mlle. Sokolowa's observation, also recently repeated by Ikeno ('98) and Arnoldi ('00), that the inner sides of the first cells are open. Mlle. Sokolowa gives the name "alveoli" to the ingrowing tubular cells of the prothallium, but this term does not seem to have much to recommend it. It is repeated by Arnoldi ('00) in his work on Sequoia.

In view of the supposed relationship of Taxodium and Sequoia, it is of interest to compare the endosperm-formation in the two cases. Arnoldi has described in some detail a double process in Sequoia which he considers to have significance from the phylogenetic point of view. The prothallial region which is to bear the archegonia is formed in the usual way by ingrowing open tubes, which finally meet in the center. This area may be either in the center of the sac alone, or may extend entirely to the tip. In the latter case, however, Arnoldi considers the tip to be lacking. The tissue at the tip does not form in the usual way, but it is produced by free cell-formation, as in the endosperm of angiosperms. This free cell-formation begins in the tips before the tubes appear in the archegonial region. In Taxodium, on the contrary, cell-formation usually begins earlier at the tip, where archegonia are to appear, than at the base of the prothallium, and firm cell walls are frequently lacking in the lower parts long after they have been established in the upper. In fact, cases are not infrequent in which the lower part of the gametophyte is in an embryonic condition, even after fertilization has occurred in the archegonia. In some cases, however, firm cell walls seem to be formed almost simultaneously throughout the spore. In the upper part of the prothallium it is always easy to see that cell-formation has proceeded by the usual growing-in method.

Fig. 55 shows prothallial tubes from near the tip of the sac after their closure on the inner side. (Mlle. Sokolowa ['90] has shown that the closure occurs when the inner ends of the tubes meet in the center.) *Fig. 56* shows the first division of a prothallial tube and the preparation for the second. By these divisions there are formed rows of cells radiating from the

center outward. *Fig. 57* represents the whole tip of a prothallium at the same stage as in *fig. 56*. Mlle. Sokolowa describes the nucleus of the open prothallial tube as remaining at the inner end during its growth toward the center, but after the formation of the closing walls the nucleus again moves back to near the periphery of the cell. From *fig. 54* we see that the first statement is true in Taxodium, at least during the very young stages. Good preparations were not obtained by me in older prothallial tubes before the closure. From Mlle. Sokolowa's figure of Juniperus, it seems that the mother-cells of the archegonia behave in this respect just as the other cells of the prothallium, and this is probably true in Taxodium also.

The prothallial formation in the lower part of the spore does not appear to me to be different in essentials from its formation above. It is only in the late development of cell walls, and not in their peculiar origin, that the difference consists. The lower part, even after the formation of cell walls, continues to increase in size long after the upper part has ceased to grow. In the ripe seed the upper end of the nucellus is no larger than at the time of fertilization, while the lower part increases greatly in size, the whole prothallium acquiring the shape of a slightly bent club. After a certain number of cell walls are formed in the prothallial tubes, nuclear divisions occur without the formation of cell walls, and there arises a multinucleate condition (*figs. 58, 59*). These nuclear divisions are generally, at least, of the mitotic type. Jäger ('99) describes a fusion of nuclei in the prothallial cells of Taxus, but I have not found the number of nuclei appreciably smaller in Taxodium even after the formation of the embryo.

DEVELOPMENT OF THE ARCHEGONIA.

The archegonia of Taxodium are disposed exactly as in the Cupresseae. They form a compact group at the base of a common depression in the center of the tip of the prothallium. Among the many hundred prothallia sectioned only three or four were found in which any variation in this arrangement occurred. In these exceptional cases there were several smaller

groups of archegonia which were separated by a few layers of prothallial cells. They were always situated at the tip of the prothallium, but sometimes faced to one side.

In *fig. 57* the initial cells of the archegonia are shown just before the cutting off of the neck cell. The nucleus is situated at the very tip of the cell and most of the protoplasm is collected around it. A very large vacuole occupies the greater part of the archegonium. In *fig. 60* the neck cell is being cut off. The nuclei in the central initials are preparing to divide. Their nucleoli are fragmented, and although this nuclear division was not followed in detail, the indications are that it is essentially like that in which the ventral canal nucleus is cut off. *Fig. 61* shows the neck divided once longitudinally. In *fig. 62* the neck cells are densely filled with starch and the amount of protoplasm in the central cell has increased greatly, especially in the lower part. In the occurrence of a single large central vacuole in the archegonium Taxodium resembles the Cupresseae and differs from all other conifers so far studied. At this stage we first notice slightly denser areas in the protoplasm at each end. The upper lies very near the nucleus and is smaller than the lower, which occupies a central position in the accumulated basal protoplasm. The nucleus of the central cell at this stage is very like that of the prothallial cells around it. In *fig. 68* there has already appeared around the archegonial group a distinct layer of sheath or jacket cells. At the basal end of the group the angles between the archegonia are filled by these jacket cells, which are at this point generally larger than on the sides. This jacket is a constant accompaniment of the archegonia in all gymnosperms with the exception of Welwitschia. Arnoldi ('00) reports that in Sequoia the layer is incomplete, only certain cells acquiring the distinctive characteristics of modified jacket cells. I have frequently found in Taxodium a cell within this sheath, which in its poverty of contents was easily to be distinguished from its neighbors, and resembles closely the ordinary prothallial cells around it. By far the larger number of the cells directly adjoining the archegonia, however, are modified in the usual way into the nourishing jacket cells. The nucleus of the central cell, at

the stage in *fig. 62*, is larger than the cells of adjoining tissue, but does not differ from them in structure. There is an abundant peripheral reticulum, staining blue throughout with gentian violet, and a nucleolus of compound structure, such as was found in the initial cell nucleus. In place of the single nucleolus there is frequently present a central group of quite distinct granules (*fig. 63*). All stages can be found between the distinct granules and the single compound structure formed by their fusion. From the nucleolus, or from the separate granules, linin threads extend which place the nucleolar matter in direct connection with the reticulum of the nucleus, and this I believe to be a constant character in nucleoli of chromatin material. That this nucleolus is largely composed of chromatin is shown by its subsequent behavior. As already mentioned, the nucleolar structure is the same in the prothallial cells and jacket cells, with the exception that in these the central or nucleolar collection of chromatin is quite inconstant in amount, the size of the nucleolus varying in proportion as the red-staining granules of the reticulum are more or less abundant.

The number of archegonia in a group varies greatly. *Fig. 64* shows a longitudinal section through a group of at least thirty-four archegonia, ten appearing in a single section. This is a larger number than has been found in any other gymnosperm, with the exception of Sequoia. The number is generally from ten to twenty, but in poorly developed prothallia there may be only a half dozen or less. *Fig. 65* is a cross section of a group of seventeen archegonia.

The neck cell very soon after its formation divides by a longitudinal wall into two cells of about equal size. This division is followed usually by another in each cell at right angles to the first, to form a tier of four cells (*fig. 94*). If the neck of the archegonium is crowded or flattened, the second division may occur in one or both of the two first-formed cells (*fig. 93*). As the archegonium reaches maturity, the nuclei of the neck cells generally divide again, and walls may or may not be formed succeeding this division. The walls when formed are very irregular in position. They are frequently somewhat inclined and

may or may not intersect the outer wall of the cell. In this way outer and inner cells are frequently formed (*fig. 66*), but two distinct tiers extending across the neck are never present. *Figs. 66, 93, 96* show the diversity that may occur in the neck. The cells are of unequal size and the number may vary from two to sixteen or even more. Very soon after their last division the neck cells begin to disorganize. They contain starch until the beginning of their disorganization, which takes place somewhat sooner here than in the jacket cells. *Fig. 66* shows an archegonium in which this disorganization is proceeding. There are present at the tip of the protoplasm of the central cell a number of bodies staining deep red with safranin, which may easily be mistaken for fragments of a disorganizing ventral canal nucleus. The last division, however, has not occurred in the central cell, and these bodies are probably the transferred remains of the broken-up nuclei of the neck cells. They are the first such bodies to appear in the archegonium, and in this stage are very conspicuous as a cap at its tip. This early transfer of nutrient material from the neck cells is probably explained by the advantage to be gained in having this transfer completed before fertilization has disturbed the relations between neck and central cell.

The jacket cells around the archegonia generally contain two nuclei each at this time (*figs. 67–69*), but this condition may be reached sooner. About the time that the ventral canal nucleus is cut off, the nuclei of the jacket cells begin to disorganize in the way already described in Cycas by Ikeno ('98) and in Ceratozamia by Arnoldi ('00). The network and the nucleoli resolve themselves into a number of deeply staining bodies, which by the disorganization of the nuclear walls come to lie free in the cytoplasm (*figs. 71–74*).

Immediately before fertilization there begin to appear in the cytoplasm of the egg the proteid vacuoles described in species of Abieteae. Such vacuoles are shown in *fig. 75* and have the same structure that has been described in other cases, but they are not very conspicuous or abundant in Taxodium. Arnoldi ('00) believes these vacuoles to originate in some cases from the

nuclei of the sheath cells of the archegonium, and thinks he has traced their entrance through protoplasmic connections in several species of Pinus and in *Abies sibirica*. From his work on Dammara and Cephalotaxus he is inclined to consider their origin as the same in these cases also. While I have not been able to establish the existence of protoplasmic connections between egg and sheath cells, the appearance in *fig. 83* strongly suggests that such connections exist, and the presence of pits in the wall of the archegonium would also imply their occurrence.

The two denser areas already noticed in the very young archegonium (*fig. 62*) have reached in *fig. 63* a size and condition retained until the initial changes which bring on the division into the central canal and egg nuclei. These areas are of dense fibrous material, and are by far the most striking features in the archegonium of Taxodium. They stain much more deeply with orange G than does the surrounding cytoplasm, and from them fibers radiate to the surface of the cell. It will be noticed that the denser part is at the periphery of the mass, but the inner part is also denser than the ordinary cytoplasm of the cell, and the whole is composed of a complex of granular fibers. The upper of these masses is the smaller and lies very near the nucleus. Fibers can be traced passing from the central mass around the nuclear wall, and they seem to be a continuation of the wall itself. That these bodies are of the same nature as the so-called kinoplasmic material, generally most conspicuous at the time of nuclear division, is evident. They show the same structure as the much less developed kinoplasmic areas already mentioned in the megaspore. Such bodies have not heretofore been described as occurring in such perfection in any case with which I am acquainted. Kinoplasmic areas have been mentioned near the nucleus at the time of its division in the archegonium of *Tsuga canadensis* by Murrill ('00), and Ikeno ('98) has figured such areas under the central cell nucleus of Cycas. Chamberlain ('99) gives one case where there are two such bodies near the egg nucleus in *Pinus Laricio*, and Blackman ('98) describes fibers of this nature radiating from the egg nucleus before fertilization. In all these cases, however, the fibrous material is not nearly so

conspicuous as in Taxodium, and in no case has a second kinoplasmic body been noticed in the lower part of the archegonium. Just before the central cell nucleus prepares to divide the kinoplasmic bodies undergo a marked change. They increase greatly in size, the central part becoming thinner, until finally the denser material, which has by this time become confined to a peripheral position, is broken up into more or less separate groups. In the upper end, one of these groups lying nearest the nucleus becomes most conspicuous, while the others become less and less distinct, their fibers finally arranging themselves into the immense aster which radiates from the inner side of the nucleus. Fibers extend around the nucleus from the center of the aster and merge insensibly into the nuclear wall (*fig. 78*). The lower kinoplasmic mass has also become broken up into separate parts, forming an incomplete ring, and during the activities in the upper part connected with the cutting off of the ventral canal nucleus these separated groups below become likewise extremely active and fill the whole base of the archegonium with conspicuous figures of various shapes, such as fans, asters, double asters, test-tube cleaners, etc. In fact the whole kinoplasmic content of the archegonium seems as if electrified. A few of these structures are shown in *figs. 90–92*.

Chamberlain ('99) figures such radiations in the egg of *Pinus Laricio* after the formation of the ventral canal nucleus, and considers them as parts of the enormously developed spindle of that division. In Taxodium, however, the kinoplasmic radiations in the lower part of the archegonium are in no way connected with the spindle above, although they are most active at the time of its formation. The function of these kinoplasmic masses is obscure, and I can suggest no explanation unless it be that the great length of the archegonia in Taxodium and the fact that it is principally at the end farthest away from the nucleus that they are exposed to the sheath cells may make it advantageous to have a more definite mechanism for the regulation of the entrance of the plastic material at this end.

[*To be concluded.*]

MITOSIS IN PELLIA.[1]

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. XLIX.

CHARLES J. CHAMBERLAIN.

(WITH PLATES XII–XIV)

JUST as an understanding of the gametophytes of the flowering plants has been gained by a comparative study of the progressive reduction of the gametophytes of the higher cryptogams, so, in our opinion, the processes of nuclear and cell division in the flowering plants will be understood only after an investigation of these processes in lower forms; and just as the pteridophytes show the transitions which have cleared up the homologies of the gametophytes, so, it seems probable, the Hepaticae, in their modes of mitosis, show the transitions which will lead to a correct interpretation of mitotic phenomena in the flowering plants. The Hepaticae, however, have received comparatively little attention from cytologists.

In 1893, Schottlander (**30**)[2] described the sexual cells of several liverworts, paying particular attention to spermatogenesis. In the antheridia of Marchantia he found that the centrosomes divide during the anaphases of mitosis, so that each daughter-nucleus is accompanied by two centrosomes; but in the egg, centrosomes were not identified positively.

In 1894 Farmer (**8**) reported a quadripolar spindle in spore mother-cells of Pallavicinia. According to this account, the chromatin of the spore mother-cell breaks up into sixteen chromosomes, four of which are then conveyed simultaneously to each of the four spores. In the same year Farmer (**9**), in collaboration with Reeves, described centrospheres in the germinating spores of Pellia. In the following year Farmer (**10**)

[1] Published concurrently in the Decennial Publications of the University of Chicago **10**: 327–345. 1903.

[2] Figures in parentheses refer to literature cited at the end of the article.

published a more extended paper dealing with spore-formation and nuclear division in Fossombronia, Pellia, Conocephalus, and several other forms. In most of these forms, centrosomes were observed to play an important rôle in mitosis. The occurrence of centrosomes in Pellia was confirmed by Strasburger (**33**) from Farmer's own preparations.

In 1899 Davis (**6**) studied the spore mother-cell of Anthoceros. In the two divisions by which the tetrad is formed from the mother-cell, the spindle during the metaphase is flattened at the poles and entirely lacks bodies which might be interpreted as centrosomes or centrospheres. The spore walls are described as being formed independently of the spindle.

The following year Van Hook (**38**), with more favorable material, confirmed Davis's statement that there are no centrosomes in the spore mother-cells of Anthoceros, but found the spindle functioning as in Lilium in the formation of spore walls. In the same paper Van Hook figured and described definite centrosomes in the vegetative cells of the gametophyte of Marchantia.

In 1901 Davis (**7**) made a detailed study of mitosis in various phases of the life-history of Pellia. Centrospheres were found during the early divisions in the germinating spore, but could not be identified in the sporophyte or in later stages of the development of the gametophyte.

At this time it hardly seems desirable to make a more extended résumé of the literature, since it is still too incomplete and indefinite to warrant generalizations. In presenting our own results, we shall occasionally refer to the preceding papers and also to papers dealing with mitosis in other groups.

MATERIAL AND METHODS.

Most of the material for this work was collected near Bonn in Melbthal and in the Siebengebirge. Early in October the spore mother-cells of Pellia are already quite deeply lobed, and occasionally a sporogonium is found in which the spores are already formed. By the middle of November nearly all of the spore mother-cells have divided and many of the spores have germinated. The winter of 1901–2, in the Rhine Province, was a

very mild one, and germination proceeded with only occasional interruption throughout the entire season. Material brought into the laboratory at any time after the middle of November developed much more rapidly than in the open, and would shed the spores within a week or ten days.

Before placing the material in the fixing agents, the calyptra was dissected away and about one-third of the sporogonium cut off with a razor, thus freely exposing the spores. In a few cases the mass of spores, held together only by the elaters, was removed from the sporogonium, but while not nearly so many spores were lost as might be anticipated, this tedious method was found to be unnecessary, since the other process readily yielded smooth sections as thin as 2 or 3 μ.

Several fixing agents were used, but only two gave thoroughly satisfactory results. These were chrom-acetic acid (0.8 gm chromic acid, 0.5 cc glacial acetic acid, 100 cc water) and a modification of Flemming's solution (0.5 gm chromic acid, 0.5 gm glacial acetic acid, 1 per cent. osmic acid 10 cc, water 100 cc). While achromatic structures stain more readily after solutions containing some osmic acid, equally good preparations were often obtained from material fixed in the former solution.

Most of the sections were cut at 2 or 3 μ, but sections 5 μ, and even 10 or 15 μ in thickness, were used in determining the number of asters and in counting chromosomes.

Haidenhain's iron alum haematoxylin, with or without a slight tinge of erythrosin, Congo red, or orange G, gave fairly satisfactory preparations, but gentian violet proved to be so much superior in differentiating kinoplasmic structures that safranin and gentian violet, sometimes with the addition of orange G, were used in most of the work. Sections were stained, usually over night, in safranin (1 gm safranin in 100 cc of 50 per cent. alcohol), then washed in 50 per cent. alcohol until all red color was removed from the achromatic structures, and then stained for one or two hours in gentian violet (saturated aqueous solution). From the gentian violet the preparations were transformed directly to absolute alcohol, where they were quickly dehydrated, the process being hastened by moving the slide to

and fro in the alcohol. Clove oil was used for clearing. The clove oil should be rinsed off with good cedar oil, otherwise the gentian violet gradually fades. When orange G was used the preparations were taken from the gentian violet, dipped a few times in water, stained for one minute in orange, and then transferred to the absolute alcohol.

In studying the preparations glass globes, filled with various solutions, served as ray filters and condensers. A light blue solution of ammoniated copper sulfate was used for most of the work, but occasionally a light violet solution of permanganate of potash, imitating the gentian violet stain, gave a sharper differentiation of the kinoplasmic structures.

While the work deals chiefly with the first three divisions of the germinating spore of *Pellia epiphylla*, and in these divisions is largely confined to the centrospheres, asters, and spindle, mitosis was studied in other phases of the life-history of this genus, and also in several other liverworts, among which were Conocephalus, Marchantia, Aneura, Pallavicinia, Scapania, Lophocolea, and Porella.

The principal results of the investigation were presented in a *Vortrag* before Professor Strasburger and the advanced students of the Bonn laboratory in February 1902, and in July of the same year a brief résumé was presented before the botanical section of the American Association for the advancement of Science.

THE SPORE MOTHER-CELL.

The spore mother-cell was observed in *Pellia epiphylla*, *P. calycina*, *Aneura multifida*, and in *Porella platyphylla*. In all of these forms the nucleus occupies a central position during the development of the lobes which are to become spores. It seems probable that the nucleus is concerned in the formation of the lobes. We found nothing to support Davis's (7) statement that the nucleus lies in one of the lobes until shortly before the first division of the mother-cell. No quadripolar spindles, like that described by Farmer (7) for Pallavicinia, were found in any of the above-mentioned forms. On the contrary, the four spores in all these cases are formed by two successive divisions, as described by Farmer (10)

and by Davis (**7**) for *Pellia epiphylla*. Unfortunately, no material of Pallavicinia in this stage was available, but the striking resemblance of Farmer's (**8**) figures to the mitoses in deeply lobed mother-cells of other Jungermanniales leads us to suggest, as Davis (**7**) has already done, that Farmer (**8**) may have misinterpreted the quadripolar figure in this genus.

THE GERMINATING SPORE.

The first, second, and third mitoses in the germinating spore of Pellia cannot be regarded as distinct types, for with diligent searching one could select a series of mitoses at the second division, or even at the third, which would be identical with a series at the first division. In fact, we have used *figs. 7*, *8*, and *19* of the third mitosis to illustrate also the same stages in the first and second mitoses. Nevertheless, it is true that, in a great majority of cases, kinoplasmic activity is most energetic during the first division, and that in succeeding divisions it becomes less and less conspicuous, until centrospheres and asters cease to attract any attention, and it finally becomes doubtful whether they are present.

THE FIRST MITOSIS IN THE GERMINATING SPORE.

As the nucleus of the germinating spore increases in size preparatory to the first division, the area immediately surrounding it becomes comparatively free from starch grains and coarser granules (*plate XII, fig. 1*). It seems reasonable to suggest that some substance, escaping from the nucleus into the cytoplasm, causes this zone and acts as a stimulus to the formation of the extra-nuclear portions of the achromatic figure. It is not impossible that such a substance might actually take the form of a centrosphere. (The origin of the aster will be considered when dealing with the second division.) After the spirem has become segmented into chromosomes the nucleus elongates and the nucleolus appears very much vacuolated (*fig. 2*). At this stage a pair of dome-shaped caps (*figs. 3*, *4*) may be recognized at opposite poles of the nucleus. These caps, which will be considered later, appear in transverse section as a delicate ring, but a similar section of the completed spindle shows a dense mass of fibers (*fig. 5*).

During the early prophases the poles of the spindle are usually rounded (*figs. 3, 4, 6*), but, as the metaphase approaches, the caps (*figs. 3, 4*) which have given the poles of the spindle a rounded form become resolved into fibers, and the poles may vary in shape from sharply-pointed figures, like that shown in *fig. 10*, to such broad, indefinite ones as those shown in *figs. 8* and *27*. Spindles with three and even more poles are not very rare. They do not originate like the multipolar spindles of the spore mother-cells of vascular plants, but are preceded by the bipolar condition or are formed through the influence of three or more centrospheres or asters (*figs. 16, 23*). During the anaphases the poles of the spindle are sometimes sharp and sometimes indefinite.

In the prophases it is plain that the achromatic figure is made up of the asters and two half-spindles (*fig. 6*). As the spindle continues to develop, some of the fibers—the mantle fibers—become attached to the chromosomes; the other fibers increase in length until they reach the opposite pole, thus forming a part of the central spindle.

While the poles are separated from each other, radiations are easily seen, and they continue to be fairly conspicuous until the spindle has reached its full length, when they rapidly disappear, losing their staining capacity first at the peripheral ends, then throughout their entire length, and finally becoming indistinguishable. When the metaphase is reached, the radiations have usually disappeared (*fig. 7*), and during the anaphases, while the chromosomes are passing to the poles, it is very seldom that any trace of radiations can be found. In the telophases, however, the radiations reappear, but are not centered in any single point. When the nuclear membrane begins to form, the radiations again become indistinct and disappear as before. Just before the spindle reaches its full length (*fig. 6*) the radiations often attain their greatest prominence, sometimes appearing as extremely coarse strands. In nearly all cases, even in very thin sections, some of the rays can be traced from the pole of the spindle to the *Hautschicht*. The diameter of the rays is usually greater at the polar end, but a slight increase in diameter at the *Hautschicht*

also is not uncommon. The rays are usually simple, but may be branched especially during the earlier stages.

It is worthy of note that the radiations are most pronounced and stain most deeply with gentian violet, while the nucleus is elongating and its poles are separating from each other; and, further, that during this period many of the radiations connect the poles with the *Hautschicht.* The explanation which we venture to suggest is that the radiations take an active part in separating the poles from each other. The fact that the radiations disappear as soon as the poles have reached their widest separation supports this hypothesis. The reappearance of the rays in the telophase does not seem to be so definitely concerned with movement, because they again disappear before the nucleus has perceptibly changed its position: still, it is possible that there may be a slight movement in the nucleus toward the center of the new cell. The reappearance, however, takes place as the nuclear membrane begins to be formed, and it may be an expression of kinoplasmic activity during the formation of the *Hautschicht* surrounding the nuclear membrane, or the rays may be contributing to the formation of the nuclear membrane itself, which, we believe, is largely kinoplasmic in its nature.

THE SECOND MITOSIS IN THE GERMINATING SPORE, WITH REMARKS ON APICAL CELL, ANTHERIDIA, NUCLEOLI, AND CHROMOSOMES.

The second mitosis is remarkably easy to fix and stain; so that, while the first mitosis, if equally well prepared, might show the early prophases with a little more clearness, our material afforded a better study of these stages during the second mitosis.

In studying the second mitosis, special attention was devoted to the centrosphere and to the origin of the achromatic structures. The terms "centrosome" and "centrosphere" are frequently confused. Until much more is known about the origin of these structures and their relation to each other, it is hardly worth while to attempt any definitions. A typical centrosphere —as the term is used in this paper—is shown in *fig. 12.* The centrosphere consists of the same substance as the astral rays and the spindle fibers. The elongated body toward which the

rays converge in *fig. 15* is also a centrosphere, and the densely staining masses at the poles of the spindle in *fig. 6*, although not organized into a definite body, consist of the same material as centrospheres and, at an earlier stage in mitosis, may have had a more definite form. We have not intended to represent a *centrosome* in any of our figures. Bodies which have the superficial aspect of centrosomes are shown in *figs. 14*, *16*, and *17*, but here the sharply staining body at the center of the centrosphere is, without doubt, the cut end of an astral ray. The structure at the upper pole in *fig. 9* certainly looks like a centrosphere containing a centrosome, but such an appearance is so rare that it seems safer to regard the sharply staining body as a chance granule. Still, it is evidently just such a body as this that Van Hook (**38**), in his recent study of Marchantia, interprets as a centrosome.

In the very early prophases a beautiful system of radiations becomes quite conspicuous. This system we regard as an aster, comparable with the asters of thallophytes and of animals. The system first appears as a few fibers converging to a point which is usually in contact with the nuclear membrane or very near to it (*figs. 11–13*), but, in some instances, may be at a considerable distance from the nucleus (*figs. 14–16*). Persistent search failed to reveal any body which could be identified positively as a centrosome or centrosphere before the appearance of the aster, and even after the appearance of the aster and centrosphere, no centrosome could be distinguished. Granules, like those shown in all the figures, were frequently found in contact with the nuclear membrane after the nucleus had begun to enlarge, and it is probable that some of the granules were centrospheres, although no method was found for identifying them before the appearance of the rays. Bodies which bear remarkable resemblance to centrosomes (*figs. 14*, *16*, *17*) and which, for a time, were interpreted as genuine centrosomes, proved to be merely the cut ends of coarse fibers. Sometimes several deeply staining points may be seen; such an appearance might easily be mistaken for a centrosphere containing several granules. In cases like those shown in *figs. 14–17*, the "granules"

are, without doubt, nothing but the cut ends of fibers. The two centrospheres in *fig. 17* are practically alike, but the one at the upper pole is represented in median section and the other in surface view, the fibers in vertical view appearing as dots. However, it must be admitted that occasionally the deeply staining points are really granules (*fig. 9*), but the cases are so rare that we have not regarded such granules as a functional part of the mitotic mechanism.

After a study of the germinating spore had failed to show any centrosomes, the nuclear figures were examined in other phases of the life-history, particularly in the apical cell and its younger segments, and in the developing antheridia. The apical cell and the rapidly dividing cells near it are quite favorable for study. The character of the mitoses in this region is represented in *figs. 9* and *10*. The lower pole in *fig. 9* shows the more usual condition, although the rays are frequently as strongly developed as those shown at the upper pole, a considerable number of the rays reaching to the *Hautschicht*. A careful examination of this figure will show that there is no definite centrosphere like those in *figs. 12* and *13*. In later stages (*fig. 10*) the spindle becomes sharply bipolar and the radiations disappear.

The antheridia were examined with particular interest because Schottländer (**30**) had reported centrosomes during all stages in the development of the antheridium of Marchantia, and Belajeff (**2**) had found blepharoplasts throughout the development of the spermatogenous cells of Marsilea. However, nothing which could be interpreted as a centrosome was found in our material, which furnished a series from the initial cell up to stages in which more than thirty cells appear in a transverse section of the antheridium. Unfortunately, the material showing the last two or three divisions preceding the formation of the spermatozoid mother-cells was not satisfactory, and, consequently, no positive statement can be made in regard to blepharoplasts, although we should assume them to be present during the last one or two mitoses.

In the germinating spore a differentiated area, already

described as a centrosphere by Farmer (9), Strasburger (33), and by Davis (7), is often found at the center of the aster. The origin and behavior of this structure, which we regard as a genuine centrosphere, are rather puzzling. While we assumed that it must appear earlier than the rays, and that the rays were developed from it, the failure to identify the structure before the appearance of the rays, and its frequent absence when it might be expected to be present, led to a careful study of the subject. The conclusion was reached that the centrosphere gives rise to the rays, but that the rays may also contribute materially to the substance of the centrosphere.

Although we have not been able to make any satisfactory study of living material, we believe that appearances warrant the theory that there is a streaming movement in the rays. Such a theory is not entirely new to zoologists. If the theory be true, when the streaming is toward the nucleus the centrosphere would increase in size, while a continued streaming toward the periphery would cause the centrosphere to disappear. In regard to the origin of the rays, nothing more definite was determined. Finely granular areas, showing a tendency to stain with gentian violet, were sometimes seen in earlier stages, but the actual formation of rays or centrospheres from these areas could only be surmised. These areas do not seem to differ essentially from those which we (4) have already observed accompanying the male nuclei of *Pinus Laricio*. In some of Miss Ferguson's (13) figures of the same species and of *Pinus rigida* the areas approach the form of definite centrospheres. The aster appears so suddenly that its mode of development is largely conjectural. In a fully developed aster there is usually an increase in the diameter of the ray at the centrosphere (*figs. 13* and *16*), and occasionally a slight enlargement at the *Hautschicht*. An enlargement of the ends of the rays, as shown in *fig. 13*, is just what should be expected if there is a streaming of material. The variability in the size of the rays and their irregularly granular character also favor the theory that they are lines of streaming material. The tendency of small nucleoli or microsomes to collect on the rays, as pointed out by Schaffner (27) in his study

of Lilium, and as is familiar to all who have seen mitoses in the embryo-sac of Lilium and similar forms, is another argument in favor of this theory.

The asters arise at opposite poles of the nucleus, but not simultaneously. Serial sections of a large number of nuclei were examined before this conclusion was reached. We can hardly understand Davis's (**7**) statement that in his studies he "has never found a nucleus with a clearly defined solitary aster beside it. This is a very important point and the search was persistent." In our own preparations of the second and third mitosis we never found anything but the solitary aster in the earliest stages. In studying this point, reconstructions were made from thin sections, and series were cut thick enough to include the entire nucleus. It is true that the first aster does not usually reach its fullest development before one appears at the opposite pole. In *figs. 14* and *15* and also in *fig. 19* (third division) there is only one aster. However, the second aster usually appears before development has proceeded so far. In spite of the fact that the two asters do not arise simultaneously we can confidently support Davis's (**7**) conclusion that the two asters do not arise by the division of a single one. We found only two preparations in which the asters were less than 180° apart, except in case of tripolar figures, which were not very rare (*figs. 16*—third pole not shown—and *23*). In early stages the two poles usually differ from each other in appearance, one pole being rather pointed and the other comparatively blunt (*figs. 21, 22, 24, 25*). Cases like *fig. 21* indicate that the blunt pole has been the last to develop. At this stage, neither pole is sharp, both being more or less rounded. The dome-shaped prominences or "caps," as they may be called, are by no means easy to interpret. In some cases the cap looks like a mere extrusion of the nuclear membrane, while in others the nuclear membrane is still intact after the caps have become quite conspicuous. The rounded ends indicate considerable pressure from beneath. That the cap is something more than a structure built up by fibers radiating from the aster is shown by its appearance and by the fact that in transverse section it presents a continuous line. The cap becomes

finely granular and suggests a delicate membrane being resolved into fibers, rather than a membrane being formed from fibers (*fig. 4*). In our opinion the cap is a delicate layer—a sort of *Hautschicht*—immediately surrounding the nuclear membrane. Were it not for the fact that the nucleus retains its form and seems to be surrounded by a membrane even after the caps have become quite conspicuous, we should conclude that the cap is only the distended nuclear membrane. At first the space between the cap and the surface of the nucleus is filled with a fluid in which no fibers or granules can be detected, but later, after the nuclear membrane has broken down, a dense mass of spindle fibers appears and occupies the space between the two caps. The caps do not seem to be different from those seen in the root tips, as described by Němec (**24**), Schaffner (**28**), and others.

The rays of the aster do not penetrate the caps, but are closely applied to them. The aster exerts a strong pull, as may be seen during the period of elongation, although the elongation is due, in some degree, to pressure from within.

As in the first mitosis, the spindle in early stages consists of two half-spindles (*fig. 26*). Until the caps become resolved into fibers they keep the spindle rounded (*fig. 26*). The caps generally break up into fibers during the metaphase or early anaphases, and the poles of the spindle may then become blunt or irregular (*fig. 27*). Occasionally the caps keep the poles of the spindle rounded even after rather late anaphases have been reached (*fig. 28*).

The polar radiations generally disappear at the end of the prophases, are absent during the metaphase and anaphases, and reappear in the telophase (*figs. 26–29*). That portion of the spindle which lies between the two caps is undoubtedly nuclear in origin. It consists of a very dense mass of spindle fibers which appear with remarkable suddenness (*fig. 20; cf. fig. 5*).

From observations on the nucleolus, we feel sure that this body contributes considerable substance to the growing chromosomes. As the chromosomes increase in size, the nucleoli become more and more vacuolated, and material which resembles that of the nucleoli is often found adhering to the growing chromosomes.

After the chromosomes have reached their full size, the nucleoli fragment, the fragments usually staining with gentian-violet. Soon the entire nuclear cavity becomes filled with granular matter staining with gentian-violet, and at this period the central portions of the spindle appear suddenly as the granular matter disappears. A few early spindles were noted in which this central portion did not seem to consist of sharply defined fibers. While such an appearance is often due to faulty methods, the sharply defined fibers in other figures in the same preparation favor the inference that these undifferentiated portions represent stages in the transformation of nucleolar matter into spindle fibers. In our opinion, these phenomena support Strasburger's (**33**) theory that the nucleolus contributes some of the material for the spindle.

Observations on the chromatin were merely incidental, but it is certainly safe to say that Pellia, in spite of the small size of its nuclei, is a favorable object for such study. As has just been mentioned, the nucleolus probably contributes something to the substance of the chromosomes. Although the chromosomes are small, they can be distinguished very early and seem to lose their identity much later than is usually the case. Mitoses in the venter of the archegonium show a longitudinal splitting of the chromosomes before the breaking down of the nuclear membrane, while in the germinating spores the splitting occurs much later.

The number of chromosomes in the gametophyte, as counted in the germinating spores and in the actively dividing region of the thallus, is eight. This number, however, is far from being constant. Both Farmer (**10**) and Davis (**7**) report occasional irregularities. In the present study, a few nuclei were found with only seven chromosomes, and nine chromosomes were counted in more than a dozen cases (*fig. 20*). Long spindles upon which the chromosomes are irregularly arranged are not infrequent, and it seems probable that such a mitosis might result in an unequal distribution of the chromosomes, and thus account for variations from the typical number (*fig. 8*).

THE THIRD MITOSIS IN THE GERMINATING SPORE.

While considerable attention was given to the third mitosis, an extended description is hardly necessary. Prominent asters

(*fig. 19*) like those of the two preceding mitoses are often present, but they are frequently absent, and the caps appear with only a few radiations (*fig. 18*) or even none at all. There are no radiations in the metaphase (*fig. 7*). In short, it is possible to select from the third mitosis a series of stages identical with a typical series from the apical region of the thallus. At the fourth and succeeding mitoses the resemblance to the usual vegetative divisions becomes more and more pronounced, while asters and centrospheres become correspondingly rare.

THE CENTROSOME PROBLEM.

The centrosome[3] problem is one of extreme difficulty, and perhaps the difficulty is greater for the botanist than for the zoologist. At least, the difficulties are different in the two cases. That there are in animals well-defined centrosomes which function as organs of nuclear division, all investigators agree, and animals or tissues in which centrosomes do not occur are regarded as exceptions. The existence of the organ is not a serious problem; rather, the more recent investigations have sought to establish the permanent or transitory character of an organ which all admit to be present during mitosis. In plants, on the other hand, even the existence of a centrosome is a problem which must be considered separately for the different groups.

It is of interest to note that centrosomes in plants were first observed in diatoms in 1886 by H. L. Smith (**31**). When Guignard in 1891 published his classic paper on fertilization, botanists at once accepted the results and confirmatory accounts appeared. Strasburger (**33**) found centrosomes in Larix, Humphrey (**18**) in Psilotum, Mottier (**22**) in Delphinium, Schaffner (**26**) in Alisma and Sagittaria, Campbell (**3**) in Equisetum, Lauterborn (**21**) and Karsten (**20**) in diatoms, and other investigators reported centrosomes in various forms ranging from the algae up to the flowering plants. In fact, the centrosome seemed to be as universally present in plants as in animals. Belajeff (**1**) and

[3] In referring to flowering plants no attempt has been made to distinguish between centrosomes and centrospheres. In describing mitosis in liverworts some writers have used these terms indiscriminately.

Farmer (**11**), however, failed to find centrosomes in Lilium. At the same time Strasburger (**35**), directing a remarkable group of investigators, attacked the problem in all the principal groups of plants. Those who studied thallophytes found centrosomes, but those who studied pteridophytes and spermatophytes not only found no centrosomes, but, in tracing the origin of the multipolar spindle, they found conditions which seemed to preclude any such bodies. Just as the discovery of centrosomes was followed by confirmatory accounts, the multipolar spindle and the non-existence of centrosomes in the vascular plants received immediate confirmation. Guignard, Schaffner, and others still continued to find centrosomes in flowering plants, although these bodies, as represented in the figures, became noticeably less conspicuous than in earlier accounts. In Guignard's (**15**) recent studies of fertilization no centrosomes are represented in the figures, and no reference to any such structures is made in the text, even during the stage at which the famous "quadrille of the centers" was formerly (**14**) described. The fact that the great majority of cytologists, with the most approved technique and provided with apochromatic immersion lenses, fail to find centrosomes in flowering plants, added to the fact that the mode of spindle-formation both in reproductive and in vegetative cells, does not require the participation of a centrosome, makes the evidence overwhelming that the centrosome, as an organ of division, does not exist in this group.

In regard to the pteridophytes, the evidence is similar, but not nearly so extensive. The blepharoplasts of pteridophytes and gymnosperms will be considered later.

In the mosses the centrosome problem has received no serious attention, doubtless on account of the small size of their nuclei. Whether there is even a blepharoplast or not still remains to be determined.

In the liverworts, no centrosome is found at any stage in the life-history. However, in Pellia and Conocephalus, and perhaps in all forms with such extensive intrasporal development of the gametophyte, a centrosphere appears during the early divisions in the germinating spore, but even in these few divisions the

centrosphere is very transitory, not persisting from one nuclear division to the next, and appearing only irregularly during the division with which it is concerned. Still, this transitory centrosphere is a functional part of the mitotic figure during the first two or three divisions. In Pellia, at the fourth division, the centrosphere may or may not appear, and in subsequent divisions it was only rarely that we could identify the body at all.

Among the thallophytes, sharply defined centrosomes have been described by competent observers who are thoroughly familiar with all phases of the centrosome problem.

In the fungi, judging from Harper's (**16**) work on various ascomycetes, a centrosome is present during the period of free nuclear division in the ascus, when it functions in the formation of the spindle. After the period of free nuclear division, the centrosome behaves in a very peculiar manner in forming the young wall of the ascospore.

The centrosome has received more attention in the algae than in the fungi. In papers by Farmer and Williams (**12**), and by Strasburger (**34**), centrosomes are described in the oogonia and segmenting eggs of Fucus.

During the early segmentations of the fertilized egg, Strasburger (**34**) was able to observe the division of the centrosome and to trace its continuity from one cell to another. In the development of the oogonium, however, no such continuity could be recognized. In the large apical cell of Stypocaulon, Swingle (**37**) found that the centrosome divides, giving rise to the two centrosomes from which the spindle is developed. He was able to recognize the centrosome even during the resting-stage of the nucleus. In the tetraspore mother-cell of Dictyota, Mottier (**23**) found comparatively large and somewhat elongated centrosomes. These bodies divide and, at least during divisions in the tetraspore mother-cell and in the early divisions of the germinating tetraspore, persist from one cell-generation to another. They develop asters and play an important part in the formation of the spindle.

Lauterborn (**21**) figures conspicuous centrosomes in Surirella and other diatoms. Karsten (**20**) also describes centrosomes in

diatoms, and his beautiful preparations, which it was our pleasure to examine, show these bodies as sharply defined as in most animal mitoses. Both Lauterborn and Karsten agree that a centrosome, or at least a body derived from it, becomes cylindrical or ring-shaped, and functions as a spindle during mitosis. The centrosomes of diatoms stain intensely and are not surrounded by a centrosphere. Lauterborn found centrosomes even during the resting condition of the nucleus and cell, but Karsten was not able to identify the body positively until the radiations began to appear. Davis (**5**) describes a centrosphere, but no centrosome, in the tetraspore mother-cell of Corallina. The centrospheres give rise to the spindle, and consequently play an essential part during nuclear and cell division. No centrospheres could be recognized during the resting-stage of the nucleus.

Thus it appears that in many of the algae well-defined centrosomes are present, at least during certain phases of the life-history, and that the centrosomes may divide and persist from one cell-generation to another, while in other algae the centrosome does not show such a degree of permanence. In the algae which we have mentioned the centrosomes are not surrounded by a clear area. In Corallina it is to be noted that there is no centrosome, but only a centrosphere. In none of the algae have centrosomes been traced throughout the life-history of the plant. In some fungi centrosomes are present during the mitoses concerned in the development of spores. Among the liverworts we doubt whether there is, at any period in the life-history, a centrosome like those described for the thallophytes. The centrosphere, appearing and functioning during only a few mitoses, has replaced the functional centrosome.

The polar radiations which are often conspicuous during mitosis in pteridophytes, gymnosperms, and angiosperms are of the same nature as those of thallophytes and bryophytes, but in the higher groups (and, possibly, in most mitoses in the lower groups) a definite centrosome, or even a centrosphere, is lacking. Centrosomes and centrospheres in vascular plants have been described and figured so frequently by such competent observers

that he would be rash, indeed, who would claim that all such accounts have no foundation except in perverted imagination and preconceived theories. That theories suggested by the accounts of zoologists and supported principally by misinterpretations of plant structures have caused exaggeration in the drawings and descriptions of botanists is probably true. While we believe that most of these centrosomes are to be interpreted as chance granules, nucleoli, pieces of chromosomes, etc., still we see no reason why a centrosome or centrosphere might not occur occasionally through atavism. The finely granular areas which have been noted during spermatogenesis in Coniferales, and the similar areas which are often seen in angiosperms, are, in our opinion, vestiges representing historically the centrosphere as it appears during the early mitoses in the germinating spore of Pellia.

The blepharoplasts described for various pteridophytes and gymnosperms are, in our opinion, to be interpreted as centrosomes. It seems to be true that in Ginkgo (**17**), Cycas (**19**) and Zamia (**39**) they appear only in the body cell and in the spermatozoids. In Marsilea, however, Shaw (**29**) traced them another cell-generation farther back, and in the same genus Belajeff (**2**) found blepharoplasts even during the earlier stages in the development of spermatogenous tissue. But granting that the blepharoplast appears during only one or two cell-generations, this does not seem to be a valid argument against its centrosome character, for in Pellia the centrosphere is clearly distinguishable during only a few mitoses, and even in the multicellular thallophytes, if the centrosome should prove to be present throughout the life-history, it is at least much more conspicuous at some phases than at others. Plants furnish numerous illustrations of the gradual reduction, and even the disappearance, of organs during phylogeny. Most botanists admit that in the earliest sporophytes all the cells were sporogenous; but, during phylogeny, portions of the sporogenous tissue became sterilized until the sporogenous tissue finally became much limited in extent and now appears only during a few cell-generations. During such reductions, functions of cells or organs may become completely changed, as in the case of the

elaters of liverworts, which are, historically, sporogenous cells and often develop like sporogenous cells, even up to the spore mother-cell stage. In the formation of the ascospore, the function of the centrosome is not the same as during the mitotic divisions in the ascus. Other examples might be cited.

That the function of the blepharoplast is somewhat peculiar must be admitted. Radiations, however, and spindle fibers, which are often the most conspicuous accompaniments of centrosomes and centrospheres, are actively concerned in movement and are not essentially different from the radiations or cilia of blepharoplasts. In form and function centrosomes present so much diversity among themselves that the peculiarities of the blepharoplast need occasion no surprise. One has only to compare the typical spherical centrosome with the rod-like centrosome of Dictyota, the hollow cylindrical spindle of some diatoms, and with the centrosome which forms the *Hautschicht* of the ascospore.

We should conclude, therefore, that centrosomes, centrospheres, and blepharoplasts are historically related, and with their radiations, spindle fibers, and cilia are only different manifestations of kinoplasmic activity, movement in all cases being the principal function.

Pellia, with the prominent aster and centrosphere of its germinating spore becoming less and less distinct in succeeding mitoses until a condition is reached resembling that which prevails in the flowering plants, presents in its own life-history a great reduction of the aster and the disappearance of the centrosphere.

I am deeply indebted to Professor Strasburger for his kindly courtesy and helpful suggestions during my work in his laboratory.

SUMMARY.

1. The principal part of the work deals with the first three divisions in the germinating spore of *Pellia epiphylla*. We have not intended to attack the excellent work of previous investigators, but rather have attempted to extend a little farther a knowledge of the phenomena of mitosis.

2. A centrosphere, but no centrosome, is very prominent during early prophases of the first mitosis in the germinating spore. The centrosphere is not present at all during the subsequent stages of mitosis. An aster is also conspicuous during the early prophases of the first mitosis, but disappears before the metaphase is reached. Radiations reappear during telophases. The aster is believed to be concerned in separating the poles of the spindle; the radiations during the telophase may be concerned in forming the nuclear membrane or a *Hautschicht* about the nuclear membrane. In the second and third mitoses, the centrospheres and asters become more and more indistinct, and in succeeding mitoses the centrosphere becomes indistinguishable, and a few irregular rays replace the aster.

3. The rays are believed to be lines of streaming material, consisting of the same substance as the centrospheres.

4. Centrosomes, centrospheres, and blepharoplasts are believed to be the same structures historically, being only different manifestations of a common kinoplasmic activity.

5. No centrosomes or centrospheres were found during mitoses in the apical region of the thallus or in developing antheridia. It was not determined whether a blepharoplast occurs toward the close of spermatogenesis.

6. The caps are derived from a *Hautschicht* surrounding the nuclear membrane. The central portion of the spindle is believed to be derived in large measure from the nucleolus.

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EXPLANATION OF PLATES XII–XIV.

All figures were made with a Bausch & Lomb camera lucida, Zeiss apochromatic immersion objective 2^{mm} 1.30 N. A., and Zeiss compensating ocular 12; magnification, about 1,500 diameters. All figures are from *Pellia epiphylla* Raddi, except *figs. 1, 2, 11*, and *12*, which are from *Pellia calycina* Nees.

PLATE XII.

(*Figs. 1–8*, mitoses in germinating spore; *1–6* first mitosis, *7* and *8* third mitosis; *figs. 8* and *10*, mitosis in apical region of thallus.)

FIG. 1. Area about the elongating nucleus has become rather free from starch grains and larger granules. Asters and caps are present.

FIG. 2. Peculiar aster at upper pole; the papilla indicates that it is pulling upon the nuclear membrane.

FIG. 3. The cap is very conspicuous and the nuclear membrane is still intact.

FIG. 4. A cap just beginning to break up into fibers. A transverse section at this stage shows a ring.

FIG. 5. Transverse section of fully formed spindle.

FIG. 6. Mitosis in late prophase; the spindle is evidently made up of two half spindles: radiations conspicuous; definitely formed centrospheres are lacking.

FIG. 7. Metaphase of third mitosis; no radiations or centrospheres are present. Figures of first mitosis are the same at this stage.

FIG. 8. Irregular mitosis (third mitosis) in an unusually large spore, suggesting how nuclei with an irregular number of chromosomes might be formed.

FIG. 9. Mitosis near apical cell; caps prominent and radiations reaching to the *Hautschicht;* at the upper pole is a granule resembling a centrosome.

FIG. 10. Anaphase in mitosis near the apical cell; no asters or centrospheres are present.

PLATE XIII.

(*Figs. 11–17*, second mitosis; *18–20*, third mitosis in germinating spore.)

FIG. 11. Very early prophase.

FIG. 12. Centrosphere and radiations.

FIG. 13. Very prominent centrosphere and radiations. The centripetal ends of the radiations have a pseudopodium-like aspect and suggest that the radiations are lines of streaming material.

FIG. 14. Centrosphere in which the cut end of a fiber resembles a centrosome. There is no centrosphere or aster at the other pole.

FIG. 15. Irregular, elongated centrosphere with prominent aster; no centrosphere or aster at the other pole.

FIG. 16. Tripolar spindle, the third pole not shown. The cut end of a fiber resembles a centrosome. The pull upon the nucleus is evident; upper aster at some distance from the nucleus.

FIG. 17. The two centrospheres are practically alike, but the upper one is shown in median section, while the lower one appears in surface view, the fibers having the appearance of granules within a centrosphere.

FIG. 18. The more usual appearance of an early prophase at the third mitosis; prominent caps, but no centrosphere or very definite aster.

FIG. 19. An exceptionally prominent centrosphere and aster at the third mitosis; no centrosphere or aster at the other pole.

FIG. 20. Transverse section of mitotic figure at the third mitosis; just before the splitting of the chromosomes, showing nine chromosomes.

CHAMBERLAIN on PELLIA

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Chas. Chamberlain, del. Ch. Austin & Fuller, Chicago

CHAMBERLAIN on PELLIA

PLATE XIV.

(*Figs. 21–29*, second mitosis in the germinating spore.)

FIG. 21. Cap more prominent at upper pole; nuclear membrane intact.

FIG. 22. Nuclear membrane has broken down at the poles, but is still intact at the sides of the nucleus.

FIG. 23. Tripolar figure.

FIGS. 24, 25. Lower cap much broader than the upper; the granular matter within the nucleus is derived largely from the nucleolus and stains with gentian violet.

FIG. 26. Late prophase; the achromatic figure evidently consists of two half-spindles.

FIG. 27. Spindle very broad at the poles; a rather common form at this stage in the first three mitoses; no radiations or centrospheres.

FIG. 28. The caps have kept the ends of the spindle rounded for an unusually long period; no centrospheres or radiations.

FIG. 29. Telophase; radiations, but no centrospheres have reappeared.

NEW WESTERN PLANTS. I.

A. D. E. ELMER.

AGROPYRON SPICATUM **pubescens,** n. var.—A tufted subalpine perennial. Culms slender, 4 dm high, cinereous pubescent below the joints. Blades mostly involute, soft pubescent on both sides, pointed, averaging 1 dm in length, divaricately disposed; sheaths pubescent, shorter than the internodes; ligule very short. Spike 7–10 cm long, glabrous or sometimes glaucous; spikelet flattened, 5–7-flowered; glumes abruptly terminated by setaceous points, lower 8 mm long, 3-nerved, upper 9 mm long, usually 5-nerved; lower palet 5-nerved toward the apex, bearing a slender divergent awn; upper palet equal in length, slightly scabrous on the nerves above the middle, emarginate; stamens 3, anthers 3 mm long.

This variety (number 1158) was collected by the writer at an altitude of 1000 m on Mt. Stuart, Kittitas county, Washington, in July, 1898. Type specimen is in the herbarium of Stanford University.

Festuca arida, n. sp.—A loosely tufted fibrous rooted annual, turning purplish at maturity. Culms varying from 3–13 cm in length, geniculate at the lower joints, striate, nearly glabrous. Leaves 1–5 cm long, involute, smooth outside, canescent inside; sheaths exceeding lower internodes, margins overlapping, smooth, the upper one inflated and partially inclosing the young inflorescence; ligule very minute, brownish. Panicle at maturity exserted, divaricately branched; rays usually single, ridged, puberulent; spikelets few, secund, sessile, 6 mm long, 2–3-flowered from near the base; glumes entirely smooth, unequal by 1 mm, lower sharply acuminate and 1-nerved, upper 3-nerved, 6 mm long; lower palet 5-nerved, nearly 6 mm long, ciliate with long and dense hairs over the entire back, bearing an awn 5 mm long; upper palet of equal length, rather broad from the middle toward the base, acuminate toward the apex, hyaline except the two nerves which terminate in fine bristle-like points; anthers

very short; seeds 4 mm long, brown, lanceolate, grooved on one side.

In habit this plant resembles *F. microstachya* Nutt. from which it is separated by its dense evenly ciliate lower palet, and from *F. microstachya ciliata* Gray by its glabrous glumes. This species (number 2196) was collected by Professor *L. F. Henderson* at North Yakima, Yakima county, Washington, May, 1892. Type specimen is in my herbarium.

Festuca idahoensis, n. sp.— Apparently a perennial, from creeping rootstocks. Culms striate, shining, 7–9 dm high, 2–3-jointed. Cauline leaves few, filiform, those of the sterile shoots equaling or exceeding the culms, striate, glabrous beneath, involute, less than 0.5 mm in diameter, canescent inside; sheaths loose, striate, smooth, the throat abruptly constricted at the leaf base; ligule a brown narrow fimbriate band. Panicle ovate, 7–12 cm long; rays 2, spikelet-bearing from below the middle; spikelets few, loosely 3–4-flowered, 10 mm or less long; glumes glabrous, broad, 3-nerved, upper 4 mm long and obtuse, lower acute, 3 mm long; lower palet broadly lanceolate, obscurely 5-nerved, 6 mm long, bearing a scabrous awn 3 mm long; upper palet equal in length, quite broad, 2-nerved, slightly bidentate at the apex; each of the 3 anthers 3 mm long; styles 2, distinct, upon the obovoid ovary.

This fescue grass is distinguished from *F. rubra* L., which it resembles, by its extremely long filiform leaves. It was collected by Mr. *L. R. Abrams*, in Smith's Valley, Shoshone county, Idaho, July, 1900. Type specimen (number 688) is in Mr. Abrams' herbarium.

Bromus magnificus, n. sp.— A scattering perennial, with creeping rootstocks, bearing few slender woolly fibrous roots. Culms 1–3 m tall, shining, erect, with 6–9 densely pubescent joints. Blades flat, scabrous on the edges, 7 mm wide, the larger ones 3 dm long, upper surface puberulent with few bristle-like hairs, lower surface glabrous, apex acuminate; sheaths soft, equaling the internodes, conspicuously striate, entirely covered with long soft retrorse hairs; ligule brownish, 2 mm long. Panicle not drooping, pyramidal in outline, 25 cm long, nearly the same in diameter at the base; rays 2–3, long and slender, subtended by a circle of fine hairs, pendulously flexuose, 1–2-branched from the middle, scabrous near the distal ends; spikelets soft,

2–3 cm long, flattened, attenuate toward the base, 7–9-flowered; glumes unequal by 1 mm, upper one 8 mm long and 3-nerved, lower 1-nerved, pubescent, both acuminate with a point 1 mm long; rachilla pubescent; lower palet pubescent around the base and on the sides below the middle, the upper half becoming scabrous, 12 mm long, prominently 3-nerved and often with minor ones between, bearing a straight scabrous awn 5 mm long; upper palet shorter by 3 mm, long-ciliate on its 2 nerves; stamens 3, their anthers nearly 3 mm long; styles 2, from below the bristle covered callous cap.

This magnificent Bromus was found by the writer only in a small shaded boggy district near Port Angeles, Clallam county, Washington, August, 1900. I have the identical species duplicated in a specimen from Yes Bay, Alaska, collected by Mr. *T. Howell*, in 1885, number 1722A. Professor C. L. Shear in his revision of the genus refers Howell's specimen to *B. sitchensis* Bong., from which it is at once separated by its pilose nodes, sheaths, and spikelets. It is most nearly related to *B. pacificus* Shear, from which it differs in its much larger size, the smooth lower surface of its leaves, the lax panicle whose rays are not secund, the slender-pointed glumes, and much shorter upper palet. Type specimen (number 1957) is in the herbarium of Stanford University.

Panicularia multifolia, n. sp.—A weak subaquatic perennial, with slender creeping rootstocks bearing fibrous roots at the nodes. Culms generally reclining, 9–12-jointed, rather soft in texture, 7–9 dm long. Blades all cauline, as many as there are joints, flat, glabrous on both sides, finely scabrous along the margins, the largest ones 14 cm long and 10 mm wide, gradually diminishing in size, all acuminately lanceolate; sheaths glabrous, the upper ones exceeding the internodes; ligule 3 mm long, hyaline, becoming lacerate. Panicle ovate, 5–8 cm long by 3 cm wide at the base, strict; rays 2, rigidly flexuose, smooth or slightly scabrous, with 3–5 spikelets, branched from below the middle; spikelets not compressed, 3–5-flowered, falling extremely early, the largest ones 5 mm long; marginal apex of the persisting glumes hyaline, subequal, lower 1 mm long, upper broadly spoon-shaped; lower palet conspicuously 5-nerved, obscurely scabrous on the margin and the nerves, 3 mm long, broadly elliptical, the hyaline apex subtended by a narrow brown band; upper palet a trifle

shorter, scabrous on the two nerves, notched at the apex, sides hyaline; anthers a little longer than 0.5 mm; styles 2, separate, inserted on the glabrous ovary.

This Panicularia was discovered in a subalpine open boggy place in the woods of the Olympic mountains (elevation 1,000 m), Clallam county, Washington, August, 1900. It is at once distinguished from *P. pauciflora* (Presl.) Kuntz, by its slender many jointed leafy stem, the uniformly small rigid panicle, and the very early falling of the flowers, leaving the glumes still attached. Of this rare species the type specimen (number 1939) is in the herbarium of Stanford University.

Panicularia flaccida, n. sp.—A tall perennial, from slender creeping rootstocks. Culm 1–2 m high, smooth and shining, 5–7-jointed, rather soft and reclining. Blades as many as there are joints, flat, finely scabrous on both sides, flaccid, 12–15 mm wide, averaging 2 cm long, lanceolate acuminate, with a strong midnerve from the base; sheaths a trifle shorter than the internodes, glabrous, many striate; ligule membranous, hyaline, 2–3 mm long, ultimately becoming lacerate. Panicle lax, subpendulous, 15–20 cm long, 9–15 cm in diameter; rays 2, 3, or 5, usually branched from or below the middle, slender, lax and flexuose, slightly scabrous on the ultimate branches; spikelet 3–5 mm long, compressed, 5–7-flowered, soft in texture; glumes persistent after the breaking up of the flowers, the upper half hyaline or in age entirely so, nerveless, glabrous, the lower 1 mm long and obtusish, the upper a trifle longer and ladle-shaped; rachilla 5 mm long, terminating in a rudimentary flower; lower palet broadly elliptical, finely scabrous on the conspicuous 5 nerves, 2.5 mm long, the upper margin hyaline; upper palet 2 mm long, rather broad, obscurely scabrous on the 2 nerves above the middle, apex with a shallow notch; stamens 3, with anthers 0.5 mm or a trifle longer; styles 2, distinct.

This grass is separated from *P. pauciflora* (Presl) Ktz. by its taller, more flaccid habit, pale color, and the larger lax panicle. It was collected by myself in a shaded boggy place in the foothills of the Olympic mountains, Clallam county, Washington, July, 1900. Type specimen (number 1940) is in the herbarium of Stanford University.

Poa laeviculmis Williams,[1] n. sp.—A robust, densely tufted,

[1] In a recent communication from Professor W. J. Spillman, Agrostologist of the Bureau of Plant Industry, U. S. Department of Agriculture, concerning this grass, I

glabrous, glaucous perennial, 7–10 dm high, with linear, plane, or mostly involute leaves, and exserted rather densely flowered panicles 1.5–2 dm long. Culms glabrous throughout; sheaths glabrous, shorter than the internodes; ligule firm, truncate, 1–2 mm long; leaf blades rather firm, usually involute, at least when dry, scabrous only on the margins, those of the culm 1–2 dm long, 3–4 mm wide, those of the innovations often 3 dm in length. Panicle lanceolate, 1.5–3 cm in diameter, pale or purplish, rachis nearly glabrous, branches erect or ascending, fasciculate, rather densely flowered, scabrous, the lower ones 5–7 cm long. Spikelets lanceolate, 6–10 mm long, 4–6-flowered; empty glumes lanceolate, acuminate, 3-nerved, scabrous on the keels, the first 3.5–4 mm long, the second somewhat longer; flowering glumes lanceolate, acute, about 5 mm long, faintly 5-nerved, minutely punctate scabrous throughout, basal hairs entirely wanting. Palea about equaling the glumes, ciliate scabrous on the keels.

Type specimen collected at Steptoe, Washington, *G. R. Vasey*, number 3026, June 25, 1900. Numbers 3034 and 3028, *G. R. Vasey*, June 1, from the same locality, are referred here, as well as number 2421A, *W. C. Cusick*, Wallowa county, Oregon, June, 1900. Number 3028 *Vasey* cited above is a very glaucous form with plane leaves, but otherwise like the type. It is closely related to *Poa nevadensis*, but is distinguished by its more robust habit, and glabrous leaves and culms. In *Poa nevadensis* the culms are decidedly scabrous below the panicles and the leaves are very scabrous. From *Poa ampla* this species is distinguished by its more strict panicles, more numerously flowered spikelets, and absence of a rootstock.

Puccinellia rubida, n. sp.—A densely tufted biennial, from numerous fibrous roots. Culms few, erect or geniculate below, slender, 2–3 dm long, smooth, naked from the middle, usually of a dark red color. Leaves very numerous from the base, 3–7 dm long, mostly falcate, strongly involute, smooth and glaucous on the outside, scabrous along the edges, rigid and pungently pointed, cauline ones 2 or 3, very short; sheaths longer than the internodes, smooth, glaucous green to purplish; ligule 1 mm long,

received a copy of Mr. T. A. Williams' diagnosis of this species. Professor Spillman kindly suggested that I include it for publication in this article, with an explanation that it has been in manuscript for some two years and would have been published sooner had it not been for Mr. Williams' death.

entire, obtuse, decurrent on the margins of the sheaths. Purplish panicle ovate, 3–7 cm long; rays 2–4, unequal in length, ascending, scabrous toward their distal ends, branched beyond the middle; spikelets usually 3–5-flowered, 5 mm long, narrowly lanceolate to linear, upon thickened purplish pedicels; glumes obscurely nerved, glabrous, purplish, lower broadly obovate and a trifle longer than 1 mm, upper 2.5 mm long, 3-nerved at the base; lower palet obscurely 3–5-nerved, of the same purple color except the brown hyaline tip, obtuse, averaging 3 mm long, broadly elliptical; upper palet at least equal in length, bifid, slightly scabrous on the 2 nerves above the middle; stamens 3, the anthers linear and nearly 2 mm long; rachis thickened at the insertion of the flowers, puberulent, terminating in a rudimentary flower, each of the joints about 1.5 mm long; styles 2, with rather short and sparsely plumose stigmas, inserted separately upon the glabrous ovary; lodicules present.

This grass is certainly closely allied to the genus Poa, in distinction from which it is chiefly characterized by its linear spikelets, shorter and very unequal glumes; it also bears a strong resemblance to the genus Panicularia, from which it is at once distinguished by its obscurely nerved glumes and palets. It is unlike *P. lemmoni* (V.) Scb. in its smaller size, purplish culms and panicles, appressed and fewer flowered spikelets. Mr. *Wm. C. Cusick* collected it in a moist alkaline meadow at Cold Spring on the Burns-Prineville road of Crook county, Oregon, June, 1901. Type specimen (number 2621) is in my herbarium.

Sitanion albescens, n. sp.—A cespitose annual or biennial, with smooth or sparsely woolly cord-like roots. Culms many, 1–2 dm high, erect, striate and glaucous green below the spike, barely exceeding the uppermost sheath. Blades numerous, coriaceous, crowded below the middle of the stem, rigidly involute, smooth and light green on the outer surface, ridged and cinereous pubescent on the inner side, slightly scabrous along the edges, usually slender and ascending, 3–8 cm long; sheaths overlapping, striate, smooth, glaucous green, persistent and marcescent near the base, open at the throat; ligule 5 mm broad, frequently produced on the sides into callous tips. Spike 7 cm long, barely exceeding the leaves, breaking up readily at its nodes, light green when in flower but soon turning purplish-gray; internodes of

rachis 3–4 mm in length, much flattened, with or without a cinereous pubescence on its edges; spikelets usually 2 at each joint, though frequently one of them is entirely sterile, 3–4 cm long including the awns, 1–3-flowered; glumes 5–7, generally entire, 7 cm long, 1–3 striate, smooth or finely pubescent, gradually tapering into a slender scabrous awn 3 cm long which is strongly recurved in age; lower palet nerveless except toward the apex, 7–10 mm long, coriaceous, smooth or puberulent, finely scabrous on the nerves above the middle, extending into an awn 2–3 cm long; upper palet 8 mm long, the two nerves smooth or slightly scabrous toward the bidentate apex; stamens 3, anthers 2 mm long; styles 2, from the apex of the ciliate callous cap of ovary; caryopsis short, stipitate at the base, smooth, plump, with a groove on the side of the upper palet.

This species was collected in the valley north of Ellensburg, Kittitas county, Washington, by *Kirk Whited*, June, 1898. It is distinguished from *S. glabrum* Sm. by its more cespitose habit, and usually by its slender rigidly involute leaves, whose sheaths are overlapping. Type specimen (number 670) is in Mr. Whited's herbarium.

Sitanion ciliatum, n. sp.—A tufted annual or biennial from strong rigid roots usually covered with a woolly matrix. Culm 1–2 cm high, striate and cinereous pubescent just below the inflorescence, strictly erect, clothed at the base with marcescent sheaths. Leaves numerous from sterile shoots, convolute to involute, averaging 7 cm in length, pungently pointed, upper surface glaucous and finely scabrous on the striae, lower surface covered with a close cinereous and usually with a longer ciliate pubescence; cauline leaves flat and broader; sheaths at least equaling the internodes, open at the throat, the lower ones cinereous and ciliate pubescent, the uppermost one cinereous pubescent and loosely including the culms; ligules very narrow, on the sides often developed into callous protuberances, decurrent down the sheath margin as a hyaline membrane. Spike 7 cm long, densely virgate, purplish brown at maturity, readily breaking up at the joints; 2 spikelets at each joint, one of which is frequently sterile, 3–4 cm long including the awns, 1–3-flowered; rachis joints 3–4 cm long, compressed, smooth or with sparse cilia along

the edges; glumes 4–6, bifid to the base, narrow, 1–3 striate, nearly smooth toward the base, scabrous on the nerves, about 10 mm long, gradually tapering into a scabrous awn 3–4 cm long which is strongly recurved in age; lower palet 8 mm long, puberulent or scabrous on the 5 nerves, extending into a scabrous purplish awn 3–4 cm long; upper palet equal in length, finely scabrous on the 2 nerves above the middle, bidentate; anthers of the stamens 2 mm long; styles 2, from the ciliate callous cap of the ovary; the two lodicules conspicuous; seed 6 mm long, pointed at the base, grooved on the side of the upper palet.

It is quite similar to *S. albescens* Elm., but may be recognized by the cinereous and ciliate pubescence of the sheaths and leaves. They may be found to intergrade, yet it seems best to recognize them as two forms. Mr. *Kirk Whited* collected it on dry rocky hills west of Wenatchee, Chelan county, Washington, June, 1901. Type specimen is in my herbarium.

Sitanion strictum, n. sp.—A densely tufted annual or biennial, with cord-like roots covered with a woolly matrix. Culms strict, 2–4 dm high, pubescent or nearly glabrous below the inflorescence. Leaves erect, conduplicate to involute, slender, sharply pointed, striate, villous on both sides, lower surface greenish, upper paler; sheaths equaling the internodes, striate, soft pubescent, usually overlapping, the upper ones loosely inclosing the stems, the basal ones persistent and becoming marcescent; ligule nearly obsolete. Spike light green, subflexuose, generally much exceeding the upper sheath, 7–11 cm long; spikelets 2 at each joint, 1–3-flowered, the lower flower usually fertile, 4–6 cm long including the awns, readily breaking up at the joints; rachis 4 mm long, compressed, shining straw color; glumes 6–8, entire or parted from near the base and of different lengths, scabrous along the hyaline margins and on the strong ridge-like nerves, gradually extending into a slender scabrous awn 4 cm long; lower palet puberulent for the lower two-thirds, scabrously 5-nerved toward the apex, 10 mm in length, generally bearing 2 short bristle-like awns at the point of insertion of the slender scabrous awn 3–5 cm long; upper palet equal in length, scabrous on the 2 nerves toward the apex, terminating in 2 unequal bristle-like scabrous awns; stamens 3, anthers 2 mm long; the 2 styles distinct; ovary

with a ciliate callous cap; caryopsis 6^{mm} in length, plump, pointed at the base, longitudinally grooved on the side toward the upper palet.

This species has been confounded with *S. villosum* Sm., from which it is separated chiefly by the character of the leaves. In typical *S. villosum* Sm. the basal leaves are short, flat, and rigid; the cauline ones are also rigid, flat, tapering from the base to the pungently pointed apex, and they are usually divaricately disposed. This species is far more common throughout the plains of eastern Washington, while *S. villosum* Sm. was discovered on rocky exposed points along the Snake river. Type specimen was collected by the writer at Parker Station, Yakima county, Washington, July, 1898, and is in my herbarium.

Hypericum bryophytum, n. sp.—A loosely tufted subaquatic annual, with smooth fibrous roots. Stems densely covered with foliage, glabrous, 2–5^{cm} long, rather weak, procumbent and branched near the base. Leaves opposite, obtuse, ovate to oblong or obovate, entire, larger ones 5^{mm} long and almost as wide, sessile, ascending, attached by a broad base, usually much overlapping, glabrous or glaucous on both sides. Flowers solitary or rarely cymosely disposed, small, barely surpassing the upper pair of leaves; the 4 sepals persistent, distinct, ascending, glabrous, usually obovate, 3^{mm} long; petals 4, very thin, shorter than or equaling the calyx, deciduous or soon withering, deep yellow, elliptical or obovate, delicately nerved, with a fine fringe of hairs along the upper edge, otherwise smooth; stamens numerous, equaling the corolla, separate, anthers orbicular; styles 3, distinct, persistent, slightly exceeding the stamens, terminated by small capitate stigmas; capsule septicidally dehiscent, tricarpellary, many seeded; seeds light brown, cylindrical, 0.5^{mm} long, puberulent, longitudinally striate.

This is a strictly alpine species, which in its native place is invariably associated with mosses, to which it bears a strong resemblance. It has frequently been referred to *H. anagalloides* C. & S., which has usually a lower altitudinal range and from which it differs in its smaller size, more numerous leaves, and fewer flowers. I collected it above timber line in the Olympic mountains, Clallam county, Washington, August, 1900. Type specimen (number 2833) is in the herbarium of Stanford University.

Orthocarpus olympicus, n. sp.—An erect annual, 2–3^{dm} high. Stems smooth, slightly angular, usually dark brown on the

angles, fastigiately 1–5-branched from above the middle, branches sparsely pubescent. Lower leaves entire, ascending, lanceolate, deciduous, the larger ones 4 dm long, plainly 3-nerved from near the base, puberulent on both sides, the uppermost with 2 narrow lateral lobes. Spike erect, 2 cm in diameter, cylindrical, not rigid, usually compact; bracts short petioled, membranous, finely hispid on the edges, elsewhere puberulent, apex of the upper ones rose-purple and nearly truncate, attenuate at base, with reticulate veins between the 3 nerves, scarcely exceeding 1 cm long and only 1 cm wide including the sharply acuminate lateral lobes 3–5 mm long; flower short peduncled, in the axil of the bract; calyx 7 mm long, somewhat saccate, hyaline except the 4 long ciliate nerves which terminate in delicate scabrous points 1 mm long; corolla tubular, bilabiate, 12 mm long, constricted just below the middle and bent upward, only the tips dull purple, conspicuously 12-nerved around the base; lower lip broadly obtuse, with 3 obsolete barely apiculate lobes, faintly canescent; upper lip slightly exceeding the lower, triangular, obscurely canescent, with a short blunt recurved apex; stamens 4, inserted on the corolla tube, mostly inclosed by the upper lip; anthers 2, oblong, 2-celled, the lower cell nearly equaling the upper; style equaling the stamens, the small stigma terminal; capsule puberulent, obovoid, loculicidally dehiscent; seeds not numerous, arranged on a central placenta, falcate, plump, 1.5 mm long, with narrow irregular corrugated wings.

This species was collected by the author in the Olympic mountains, Clallam county, Washington, August, 1900, at an elevation of 1000 to 1500 m. It seems to be rare, and in my opinion it is wholly unlike *O. imbricatus* Torr. in its smaller, less coriaceous, and broadly obtuse or truncate bracts. Type specimen (number 2574) is in the herbarium of Stanford University.

HERBARIUM OF LELAND STANFORD JUNIOR UNIVERSITY.

BRIEFER ARTICLES.

POSITIVE GEOTROPISM IN THE PETIOLE OF THE COTYLEDON.

(WITH ONE FIGURE)

In a former paper[1] on the geotropic responses of young hypocotyls and the cotyledons of some monocotyledons, I showed that the downward curves they execute are in response to stimuli received by the root tip. This note is to report the same phenomenon in yet another category of stem-organs—in the petiole of the cotyledon. The accompanying figure shows a seedling of *Aesculus Californica*. When the buckeye germinates, the first structures to elongate are these petioles, and in whatever position the seed is lying they grow enough to bend in such a way that when the active growth of the root begins it is directly downward. I have observed the germination of the seeds in all cardinal positions and found this true, whether the curve was alike in the two petioles or was accomplished by more rapid growth of either one.

The analogy to the positive geotropism in cotyledons and hypocotyls is close enough to convince one that these petioles act under the influence of the root tip. Measurements of the growing region corroborate this view. In a rather advanced seedling, whose root was already 7^{mm} long at the beginning of the experiment, the growing region was more than 15^{mm} long. It was placed horizontal and left 29 hours, and by that time the tip was aimed almost vertically downward. The most considerable elongation was in zones 6–8, but it amounted to 3^{mm} (measured midway between the convex and concave sides) between the 10^{mm} and 15^{mm} lines. The curve began about the 14^{mm} mark, and had the least radius at about 12^{mm}, but continued toward the tip into zone 6.

In this case there was evidently an apical growing region, consisting partly of root and partly of shoot, which curved where it grew. Likewise in both root and shoot the curvature was at first more largely

[1] Bot. Gaz. 31 : 410. 1901.

in the shoot, while before the close of the 29 hours the zone of most rapid elongation had moved forward into the root. So far as concerned its geotropism it behaved as if all root. In older roots the growing region is shorter, as would be expected in correlation with their being decidedly more slender, and the curve is correspondingly nearer the tip. As the cotyledons serve solely as a food store, they remain in or on the ground, where the seed germinates, and there is no later growth with negative geotropism, such as occurs, for instance, in the hypocotyl of Lupinus.

A hypocotyl is practically absent in the Aesculus seedling, the root beginning hardly a millimeter below the insertion of the petioles of the cotyledons. The lower part of these petioles, however, grows more or less firmly into a tube by the coalescence of their margins. The curve may occur in this tube, as in the figured and measured specimens, or in the upper ends where they are usually separate. The tube entirely surrounds the plumule, and the curve is ordinarily far enough up in the petioles so that the lower end of them with the enclosed plumule is brought into the vertical line with the root.

The plumule being below the curve, and already in the vertical line, when it grows it does not escape from the petiole-tube by growing out of the top of it, but out through its side. It does not have to force this passage, which it could hardly do. But at the height where it is to escape, and on that side, there is a vigorous but strictly localized growth, without a corresponding elongation elsewhere in the same zone. The result is the same as when the two guard cells of a stoma with rigid, fast ends enlarge; they spread apart in the middle. In the same way the two petioles pull, or rather push, apart, opening a wide crack, often two or three times as wide as it need be, to permit the free growth of the plumule. What stimulus determines this remarkable localized growth I do not know.

This buckeye is very abundant here, and its large seeds with powerful roots make it an inviting subject for any work on the pressure exerted by the growing roots, or involving their mutilation. For these ordinary experiments on geotropism, reported here, it is well adapted, because it can easily be marked accurately, and especially because of the ease of fixing the position. The cotyledons are so large and heavy that it is only necessary to make plane the proper side and put the seedling down on that surface in a dish containing a little water. The plane of the cut surface determines the inclination of the growing region. If older seedlings are to grow downward, the cotyledons

are cut in the same way and then placed on pedestals. When the whole active part of the seedling is under water growth ceases, but in moist air they do very well. Seeds kept some months in the very dry air of the laboratory refuse to germinate.—EDWIN BINGHAM COPELAND, *Stanford University, California.*

CONTRIBUTIONS TO THE BIOLOGY OF RHIZOBIA.

III. NOTES ON THE WINTER AND EARLY SPRING CONDITIONS OF RHIZOBIA AND ROOT TUBERCLES.

THE major observations here recorded were made during the winter and early spring of 1893 and 1894; incidental observations were also made during subsequent winter seasons. The object was to obtain more definite information regarding the permanency of leguminous root tubercles and the viability and natural resistance of rhizobia to low temperatures, more especially low temperatures with frequent changes to higher temperatures as in the winter months of the central states, Illinois in particular. Sudden changes of temperature, though not necessarily fatal to life, have a pernicious effect upon low organisms. The effects of temperature and other climatic conditions become gradually less with increase in depth of soil. The organisms found in the surface soil are most directly exposed to the pernicious climatic changes.

From the following table of mean monthly averages for the months of November, December, January, February, and March, 1902–3, with a list of coldest days of each month, it will be seen that the variation in temperature was considerable. Very cold weather (— 10° to — 15° F.) did not continue for more than a few days at a time.

Month	Min. ° F.	Max. ° F.	Mean ° F.	Coldest days ° F.
November	25.9	52.1	37.3	6, 10, 14, 16, 18, 18.
December	19.9	38.4	30.0	— 6, 1, 3, 5, 6, 6, 8, 9.
January	20.3	39.7	29.4	—21, —12, 12, 10, 12.
February	15.6	33.9	24.7	— 5, 2, 3, 3, 7, 8.
March.....	32.9	55.6	43.5	10, 11, 12, 16, 21.

The humidity during the months indicated was somewhat above the average for the state of Illinois. The ground was covered with snow during parts of the months of January, February and March. Soil covered by snow banks was not frozen at any time. The open unprotected soil was frozen to a depth of about eighteen inches during January, February and the early part of March.

The prevailing opinions held have been that leguminous root tubercles are destroyed at the close of the seasonal vegetative period and that the cytoplasmic and albuminoid contents of rhizobia are absorbed or assimilated by the host plant. Upon examining the roots of *Trifolium pratense* late in November it was found that the tubercles present were normal in appearance. Microscopic examination showed that rhizobia (*R. mutabile*) were present in smaller numbers than during the summer months. The highly refractive sporoids (fatty particles) were more plentifully present and more distinct. Since the tubercles were intact the question arises, what became of the missing rhizobia? It is highly probable that through lack of nutriment they became famished and finally died. Most organisms present reacted very feebly with the usual cytoplasmic stains, indicating a reduction in the cytoplasm. In such rhizobia the above mentioned sporoids were very distinctly visible and took the stain readily. Each organism showed from one to five such sporoids, more usually one in the neck portion and two or sometimes three or four in the body of the Indian club-shaped rhizobia, and quite generally occupying a position next to the cell-wall. They are not uniform in size and form. They stain a reddish brown with iodin tincture and are very clearly shown in an aqueous solution of corrosive sublimate. Infecting threads (Infectionsfäden) are present in apical areas and show no special modifications. In some tubercles they seemed to be wholly wanting. When present they are usually very distinct for several reasons, because of the lesser abundance of rhizobia and also because of the greater thickness of the cellulose wall. They are almost entirely empty, containing only a few small motile forms of the rhizobia. The walls of the filaments attain their maximum thickness late in the fall of the first season; the following season they do not increase in thickness, though they become refilled with motile rhizobia, finally rupturing the wall or escaping through breaks already existing. Thus they again refill the cells with mature, greatly modified, non-motile rhizobia. During the second year's growth of the tubercles, the filaments often disappear entirely. They may be destroyed or assimilated by the rhizobia or by the host plant. In some instances the filaments become separated from the cell-walls because of the tension due to the growing cell. The separation may take place in any part of the threads, but more commonly where they unite with the cell-wall. During the second season the partially emptied infected area of tubercles again becomes tensely filled with mature rhizobia, through the multiplication of organisms

found in the infecting threads which are found in the apical areas of tubercles and in the cells just within the phellogenic layers. Additions to the growth of the tubercles are also made at these points. The starch, which was deposited just outside of these meristematic areas in the fall of the year, is now again assimilated by the host plant.

It is evident that perhaps about one-half, or somewhat less, of the rhizobia existing within the infected areas of tubercles are killed during the unfavorable winter conditions. Freezing alone does not kill them; it is rather a combination of conditions, the lack of food supply perhaps being the most important. The tubercles and soil examined were taken from near the surface of the frozen ground when the temperature was from -10° to -20°F. Cultures were made from the tubercles as well as from the soil by the usual plate isolation methods. The growths showed the presence of rhizobia and other soil bacteria. Streak and stab cultures were also made from the infected area of tubercles. A careful examination of growths and culture media at the point of inoculation showed a number of impoverished tubercle organisms which had evidently lost the power of dividing. These stained very feebly and the cell-wall was partially destroyed, having a roughened perforated appearance. Soil cultures showed the presence of rhizobia, besides numerous soil bacteria.

Examining tubercles which were more deeply situated, about one foot below the surface of the soil, showed that the destruction of rhizobia had been less and the number of dead but not destroyed rhizobia was also less, which would seem to indicate that cold was also a factor to be considered in the killing of rhizobia. It seems probable that rhizobia of tubercles below the freezing depth develop and multiply to some extent, though the tubercles do not increase in size, as is indicated by the tensely filled glistening appearance of such tubercles. A careful examination of a number of such tense, brittle tubercles showed that they contained numerous rhizobia imbedded in a large amount of a mucilaginous substance. The cells of the infected area were loosely united and almost spherical in form. The contents of these tubercles require further study.

The observations were made chiefly upon tubercles of *Melilotus alba*, *Trifolium pratense*, and *T. repens*, and the conclusions with reference to these plants are that root tubercles are mostly biennial, the tubercles attaining their full growth during the first year and gradually dying and decaying toward the close of the second year.[2] With the

[2] New tubercles are, of course, added each season along with the development of new rootlets.

death and decay of the tubercles most of the contained rhizobia also die, but some escape into the soil and serve to infect other roots of the same host species. No comparisons were made between summer and winter soil to determine the comparative number of rhizobia present. It is, however, highly probable that the conditions are much as with the rhizobia of summer and winter tubercles. The tubercles of annuals, like the bean, pea, Spanish pea, etc., die and decay at the close of the vegetative period and many of the contained rhizobia escape into the soil. Many are no doubt killed and assimilated by the host plant shortly before the close of the vegetative period; according to some authorities during the seed- and fruit-forming period of the host plant.

The following are the conclusions based upon the observations recorded:

1. A considerable number of rhizobia of biennial and perennial plants forming root tubercles are killed during the winter months.

2. Root tubercles of perennial herbaceous legumes attain their full growth during the early part of the first season.

3. Most root tubercles of perennial herbaceous legumes die and decay at the close of the second season, returning only a part of the contained rhizobia to the soil. Many of the rhizobia are assimilated by the host plant during the period of fruit development.—ALBERT SCHNEIDER, *California College of Pharmacy, San Francisco.*

CURRENT LITERATURE.

BOOK REVIEWS.

Bacteriology.

THE American edition of Muir and Ritchie's well-known *Manual of Bacteriology*, edited by Dr. N. McL. Harris, is a worthy representative of American bacteriology.[1] The manual, designed primarily for medical students, has been greatly improved by Dr. Harris by additions at points where the previous English editions were lacking. The increase in size to octavo and the introduction of a number of new illustrations, including some photomicrographs of excellent typographical execution, add much to the general appearance of the book, while the enlarging of the chapters on methods brings the manual nearer to the student as a source of practical information on laboratory technique.

The importance of sanitary bacteriology is recognized by the introduction of a new section on "Bacteria in air, soil and water." The increasing scope of bacteriological examinations in preventive medicine would perhaps warrant even more extensive consideration than is accorded to the subject. The chapters on the special diseases have been revised to include our more recent knowledge of bacterial etiology and diagnosis, and the theories regarding immunity are set forth in so lucid a manner that the student should obtain a most excellent working basis for further study.

As in previous editions, the style of the manual is interesting and the reader is more than ever impressed with the author's conception of bacteriology as an organic part of pathology and medicine.— E. E. IRONS.

MINOR NOTICES.

VON WETTSTEIN[2] has recently published a second paper on Neo-Lamarckian principles in relation to Darwinism. His position is a somewhat intermediate one between these extreme schools, whose views are discussed in relation to one another and to the mutation theory of DeVries. — B. M. DAVIS.

Trees and Shrubs, number 2, by Charles S. Sargent,[3] was issued in May, 1903, and contains illustrations of two species of Guatteria from Central

[1] MUIR and RITCHIE, Manual of Bacteriology. 8vo. pp. xx + 565. New York: The Macmillan Company. 1903. $3.50.

[2] WETTSTEIN, R. VON, Der Neo-Lamarckismus und seine Beziehungen zum Darwinismus. pp. 30. Jena: Gustav Fischer. 1903. *M* 1.

[3] SARGENT, C. S., Trees and shrubs, pt. II, pp. 51–99. *pls. 26–50.* Boston and New York: Houghton, Mifflin & Co. 1903. $5.00.

America, descriptions and plates of eight new species of Crataegus, one of Malus, one of Solanum, one of Picea, and a new hybrid Cornus. There are also illustrations and descriptions of thirteen other species, previously described elsewhere.—C. R. B.

THE CHARALES of the province of Brandenburg have been described by Holtz[4] in an account of 136 pages which is well illustrated. This volume is one of a series that is to treat the cryptogamic flora of this region. The account of the general structure of this group is very clear, the notes on distribution are full, and the arrangement good. It seems to be an excellent piece of work of its character.—B. M. DAVIS.

RINGLE AND KENOYER have attempted to meet the demand on the part of district-school teachers and high-school pupils for a simple means of determining the local spring flora.[5] The addition of laboratory hints, outlines of morphology, and directions for the preparation of an herbarium, makes it more than a manual, but its subject-matter is wholly inadequate if it is supposed to comprehend the entire botanical knowledge of the high-school graduate.—J. M. WESTGATE.

AS A COMPANION book to *Our Native Trees* Miss Keeler[6] publishes a similar work on shrubs. The work contains very excellent descriptions of nearly all the native northern shrubs and many common cultivated ones. Accompanying each description is a well-made half-tone illustration of the form. In many instances so good are these figures that they are sufficient to identify the plants. Each description contains many interesting facts about the habits of the shrub. A very simple key is given by which one who is not a professional botanist may identify them. Indeed, the book is intended for the amateur, the lover of nature, and those interested in landscape gardening.—H. N. WHITFORD.

THE LEGUMINOSAE collected in the states of Michoacan and Guerro in Mexico during the years 1898 and 1899 by Eugène Langlassé have been elaborated by the late Marc Micheli.[7] The purpose of Langlassé's exploration was mainly horticultural and the collection of dried plants for the herbarium was purely incidental. Moreover, his collections of all kinds were primarily of the plants having some interest for the horticulturist, or of importance from the point of view of agriculture or forestry. In spite of this, the

[4] HOLTZ, L., Characeen. Kryptogamenflora der Mark Brandenburg, Vol. IV, Part 1. pp. vi + 136. Illustrated. Leipzig: Gebrüder Borntraeger. 1903.

[5] RINGLE, W. E., and KENOYER, L. A., Students' botany of eastern Kansas. 8vo. pp. v + 213. Topeka: Crane & Company, 1903.

[6] KEELER, HARRIET L., Our northern shrubs and how to identify them. 8vo. pp. xxx + 521. *pls. 205. figs 35.* New York: Charles Scribner's Sons. 1903.

[7] MICHELI, MARC, Leguminosae Langlasseanae récoltées dans les états Mexicains de Michoacan et de Guerro pendant les annees 1898 et 1899, par Eugène Langlassé. Mém. Soc. Phys. d'Hist. Nat. Genève **34**. 245–294. *pls. 28.* 1903.

number of novelties which M. Langlassé brought back is rather remarkable and indicates the richness of the country in new forms. In the Leguminosae, represented by 237 numbers, M. Micheli finds 26 new species and a new genus, Goldmania, the latter described by Mr. J. N. Rose, of the U. S. National Museum, while many other of the species listed have only recently been published from collections of American botanists. The novelties are illustrated by twenty-eight elegant lithograph plates.—C. R. B.

A CRITICAL ACCOUNT of the algae of northwestern America by Setchell and Gardner[8] has appeared as one of the admirable publications of the University of California. In this paper of 250 pages, with 10 plates, are listed all the known species of algae, excluding the diatoms and desmids, found north of Cape Flattery to the region of Kotzebue Sound in the Arctic coast of Alaska. The authors have had access to a large number of collections, many of them gathered by government parties and other expeditions, and have themselves visited much of the region. They have handled, therefore, probably the largest amount of material ever brought together from this region.

The species are enumerated under the most generally accepted classification, with explicit references to all the specimens examined, and with critical notes on their conditions and peculiarities of structure, habit, and distribution.

A large number of new species and forms are described and figured. Although attention is called to them by printing the names in heavy type, the taxonomic compiler must laboriously pick them out from the main body of the account. A list of these new species properly indexed would have obviated this difficulty.

The authors have refused to change names or upset well-established nomenclature by the application of arbitrary rules, "holding that a name which has been recognized for a quarter of a century, or thereabouts, is to be considered fixed and not to be unsettled simply because another may have been proposed earlier, but hitherto neglected for good or even for no real reasons."—B. M. DAVIS.

NOTES FOR STUDENTS

KNY[9] finds in three plants (*Lupinus albus*, *Lepidium sativum*, *Vicia sativa*) that diffuse daylight retards the growth in length of soil roots, while darkness is advantageous to it.—C. R. B.

ZEILLER describes[10] the occurrence of species of Zamites, Sphenopteris, and Pagiophyllum, from the Upper Jurassic of the province of Catalonia in

[8] SETCHELL, W. A., and Gardner, N. L., Algae of northwestern America. Univ. Calif. Pub. Bot. **1**: 165–418. *pls. 17–27*. 1903.

[9] KNY, L., Ueber den Einfluss des Lichtes auf das Wachsthum der Bodenwurzeln. Jahrb. Wiss. Bot. **38**: 421–446. 1902.

[10] ZEILLER, RENE, Sobra algunas impresiones vegetales del Kimeridgense de Santa Maria de Meya. Memor. Real Acad. cienc. y artes Barcelona.

Spain. Two new species, *Pityophyllum flexile* and *Pseudoasterophyllites Vidali*, are likewise figured and described. The first is considered, as the name indicates, to represent fossilized leaves of a species of Pinus. The second after a process of exclusion, the author is disposed to regard as of cupressineous affinities.—E. C. JEFFREY.

IN Comptes Rendus de l'Académie des Sciences, Paris (March 30, 1903), M.C. Queva gives an account of the structure of the rootlets of *Trapa natans*.[11] These are of particular interest because they present the only case known among the phanerogams of a monarchous root. Roots of this type have in the past only been known for the lycopods (unless the rather doubtful case of Ophioglossum be also included), and indeed are almost diagnostic of the radicels of that group.—E. C. JEFFREY.

FROM AN extended study of protoplasmic streaming in plants, carried out by Ewart,[12] it appears that these movements are produced by the energy of surface tension, this being made available perhaps, by the action of electric currents transversing the moving layers. Such currents could be maintained by chemical action in the protoplasm. The movement does not depend directly upon oxygen access, for species of Chara and Nitella continue to exhibit motion for six to eight weeks in entire absence of free oxygen. —BURTON E. LIVINGSTON.

FROM INTERNAL structure and by comparison with specimens having the exterior preserved, Weiss[13] identifies a reproductive branch of a lepidodendroid found near Stalybridge, England, as belonging to the well-known species *Lepidophloios fuliginosus*, and constituting its reproductive branch. The identification is of interest, not only because it reveals the nature of the reproductive main axis of *Lepidophloios fuliginosus*, but also because the axis in question differs from other axes of the genus in having a biseriate instead of a quincuncial arrangement of the cone-scars.—E. C. JEFFREY.

THE curiously modified leaf-members, found in a few living ferns, *e. g.*, *Hemitelia capensis*, but occurring much more commonly in fossil genera, were examined by Potonié[14] from the physiological and morphological standpoints. He concludes that the structures in question are water-absorbing organs, and are specialized pinnae or pinnules as the case may be. The aphlebia or modified pinnae of *Hemitelia capensis* have been compared by

[11] QUEVA, C., Structure des radicelles de la macre. Compt. Rend. Acad. Sci. Paris **136**: 826–7. 1903.

[12] EWART, A. J., On the physics and physiology of protoplasmic streaming in plants. Proc. Roy. Soc. London **69**: 466–470. 1902.

[13] WEISS, F. E., A biseriate halonial branch of *Lepidophloios fuliginosus*. Trans. Linn. Soc. London Bot. II, **6**: 217–235. *pls. 22–26*. 1903.

[14] POTONIÉ, H., Zur Physiologie und Morphologie der fossilen Farnaphlebien. Ber. Deutsch. Bot. Gesells. **21**: 152–164. *pl. 8*. 1903.

Goebel, in regard to their physiological function, with the whole leaf-organ of the Hymenophyllaceae, and the present author suggests that the aphlebia of fossil ferns are to be similarly interpreted.— E. C. JEFFREY.

THE CONDITIONS governing the germination of the spores of the brown rust of bromes (*Puccinia dispersa* Erikss.) have been closely studied by Ward.[15] This rust is an excellent example of a parasite very closely restricted to certain species of hosts, yet forms were found bridging over widely separated sections of the genus. It is interesting to know that these uredospores retain their vitality for long periods, month-old spores germinating readily, and certain forms after sixty-one days. But the conditions governing the germination of uredospores are very uncertain, for there are internal factors, such as the age of the spore-bearing mycelium and degree of ripeness, beside the external factors of temperature, aeration, moisture, etc.— B. M. DAVIS.

PALLADINE AND KOMLEFF[16] have determined that the respiratory energy of cut etiolated leaves of *Vicia faba* placed in solutions of cane sugar is greatest when the solution has a concentration of about 5 per cent. This fact seems not to depend upon sugar assimilation, for the latter increases with the concentration at least as far as a 20 per cent. solution, the highest concentration tested. But the respiratory energy is greatest when there is the largest amount of insoluble proteid substances present in the leaves, a condition attained in a 5 per cent. solution of cane sugar. When the leaves are transferred from one concentration to another respiration is augmented with decrease and diminished with increase of concentration. This supports the view that foods are not directly consumed in respiration.— BURTON E. LIVINGSTON.

"THE AECIDIUM as a device to restore vigor in the fungus" is the subject of a short discussion by Professor Arthur,[17] who believes that the aecidium with the accompanying spermogonia represents the original sexual stage of the rust. It appears that wheat infected from aecidial spores will produce teleutospores (black rust) much more quickly than if the infection be through uredospores, and it is well recognized that the black rust is more injurious to the wheat than the red rust. Hence the author regards the aecidiospore as more virile than the uredospore, since it produces a more vigorous and harmful parasite. The question, however, suggests itself whether this added virility has really any connection with the organ called the aecidium. It is possible

[15] WARD, H. M., Further observation on the brown rust of the bromes, *Puccinia dispersa*, and its adaptive parasitism. Ann. Mycol. **1**: 132–151. 1903.

[16] PALLADINE, W., and KOMLEFF, A., L'influence de la concentration des solutions sur l'énergie respiratoire et sur la transformation des substances dans les plantes. Rev. Gén. Bot. **14**: 497–516. 1902.

[17] ARTHUR, J. C., The aecidium as a device to restore vigor to the fungus. Proc. Soc. Prom. Agric. Sci. **23**: 1–4. 1903.

that the mere change of host (wheat to barberry and back to wheat) may give to the rust that variety of life conditions which is generally beneficial to every organism, in contrast to monotony of food and environment.— B. M. DAVIS.

IKENO[18] has continued his studies on spore formation in Taphrina which were first reported in Flora **88**: 229. 1901. He finds essentially the same conditions in several species that he described for *Taphrina Johansoni*. There is always the fusion of two nuclei in the ascus preliminary to spore formation. The chromatin material in the fusion nucleus may split up into a number of fragments, which become scattered in the cytoplasm by the dissolution of the nuclear membrane and organize very small nuclei. Or, division may proceed more regularly through successive halving of the chromatin, sometimes accompanied by simple mitotic phenomena. There is generally at the end extensive multiplication of the nuclei by fragmentation and division of the spores by budding. No asters were discovered to cut out the spores as in the higher Ascomycetes, but the cytoplasm seems to gather more densely around the nuclei and form the spore wall. There is no evidence in the ascus of cleavage by constriction.— B. M. DAVIS.

THE LARGE PROPORTION of the seeds of the darnel (*Lolium temulentum*) are infected with a fungus which causes the development of a substance (lolium) with toxic effects upon man and certain carnivorous animals, but not injurious to pigs, cattle, or geese. This interesting parasite has been recently studied by Freeman.[19] No spores are known, and the fungus apparently passes from one generation of the host to the next with the seed. It does not appear to harm the darnel; on the contrary, the infected seeds seem to be larger and better developed than those free from the fungus. Infected seeds germinate very well. There is, therefore, the possibility of an advantage to the host, but this is not positively known. The relationships of the fungus have been much discussed, but in default of spore fructifications the conclusions are mere speculations. The invasion of the young seedling from the coats of the seed and the later appearance on the ovaries is smut-like, but there are also points of resemblance to ergot, and especially to an ergot that frequently attacks Lolium in England.— B. M. DAVIS.

A MEMOIR on Todea, of the same admirable character as former works of the senior author on ferns possessing at the same time fossil and living representatives, is published by Seward and Ford.[20] The anatomy of the mature stem of *Todea barbara*, *T. superba*, and *T. hymenophylloides* is

[18] IKENO, S., Die Sporenbildung von Taphrina-Arten. Flora **92**: 1–31. *pls. 1–3*. 1903.

[19] FREEMAN, E. M., The seed-fungus of *Lolium temulentum* L., the darnel. Phil. Trans. Roy. Soc. London B. **196**: 1–27. *pls. 1–3*. 1903.

[20] SEWARD, A. C., and FORD, SYBILLE O., The anatomy of Todea with notes on the geological history and affinities of the Osmundaceae. Trans. Linn. Soc. London Bot. II. **6**: 237–260. *pls. 27–30*. 1903.

described. The results of Faull in the two former species are in the main confirmed. The last species is of interest because, like *Osmunda cinnamomea*, it has an internal endodermis surrounding the pith in the adult; but unlike the latter this does not appear in the young axis. The figures and description of the authors leave some room for doubt as to the entire accuracy of of this statement, for they do not follow the central cylinder to a sufficient height in the sporeling to exclude their having missed the first appearance of the internal endodermis. An admirable résumé of the fossil Osmundaceae is given, from which it appears how unsatisfactorily meager is our knowledge of this interesting group of ferns, particularly on account of the paucity of specimens from the Mesozoic.—E. C. JEFFREY.

VARIOUS PERIODIC phenomena in connection with the growth and development of plants are well known. Many of these depend upon conditions at present wholly unknown and are designated, therefore, as autonomous. As illustrations may be cited the grand period of growth, the variation in the length of internodes and often of interfoliola (by which Münter long ago designated the spaces between the pinnules on the common petiole). Tammes[21] has endeavored to determine the influence of the presence or absence of leaves upon some of these periodic phenomena. Thus he finds that if all leaves be removed from an annual shoot the periodicity in the length of the internodes is not disturbed, the elongation of the cells only being interfered with, so that the internodes remain shorter than in the living shoot. But the removal of one or more leaves does disturb the periodicity. Certain internodes have less length than in the normal shoots. One would expect that each leaf would affect only the growth of those internodes adjacent to it, but this is not the case, internodes above as well as below the removed leaves being influenced. Often more strikingly than the annual shoots the interfoliola show a similar effect from the removal of leaflets.—C. R. B.

LIDFORSS[22] has investigated the geotropic response of some spring plants whose geotropism is influenced by variations of temperature. These are almost exclusively plants which conclude their development before the warm season. He finds that many of these shoots at lower temperatures are diageotropic, while at higher temperatures they are apogeotropic. This he considers a typical case of dynamic anisotropism. Somewhat similar reactions, however, may be due to changes in temperature alone. In general those shoots whose geotropic reactions are influenced by alterations of temperature are more or less epinastic at lower temperatures, but this epinasty, which reaches its maximum a little above zero, disappears completely at temperatures above 20 degrees. At low temperatures darkness may also affect

[21] TAMMES, T., Die Periodicität morphologischer Erscheinungen bei den Pflanzen. Verhandl. Konigl. Akad. Wetens. Amsterdam. II. **9**: no. 5. 1903.

[22] LIDFORSS, B., Ueber den Geotropismus einiger Frühjahrspflanzen. Jahrb. Wiss. Bot. **38**: 343–376. *pl. 3*. 1902.

geotropic reactions, so that shoots diageotropic in light become apogeotropic in darkness.

Lidforss holds that the term "psychrocliny," introduced by Vöchting, includes a series of phenomena which doubtless have the same ecological importance, but are in no wise equivalent physiologically. Unless the term be reserved as a physiological one for those cases in which temperature actually produces a modification of the geotropism, he thinks it should be abandoned.—C. R. B.

A NUMBER of Bulletins of the United States Agricultural Department deserve brief mention.

VON SCHRENK[23] discusses among other subjects the relation of water to the decay of timber, how timber is seasoned, seasoning tests with lodgepole pine and oak, and tests with telephone poles.

GRAVES AND FISHER[24] treat of the woodlands of southern New England. Improvement cuttings, reproduction cuttings, platting, pruning, protection of the woods and other subjects are well handled.

In another bulletin VON SCHRENK[25] has investigated the cause of the blue color of dead wood in *Pinus ponderosa* (which he finds due to the blue fungus, *Ceratostomella pilifera* (Fr.) Winter), the effect of coloring on the value of the wood, the reason for the decay of wood and how prevented, and whether it would be possible to use the dead wood before it decays. The bark beetle (*Dendroctonus ponderosae*) spreads the fungus, therefore it is recommended that the dead wood be removed at once, for standing beetle-infested trees serve to spread the insect.

HERTY[26] shows that an improved method of turpentine orcharding will increase profits sufficiently to warrant its adoption by any turpentine operator.—H. N. WHITFORD.

VAN WISSELINGH, in his earlier papers upon karyokinesis in Spirogyra, devoted his attention to the nucleolus and the nuclear net-work. In the fourth paper[27] of the series he deals with the nuclear membrane, the spindle, and the walls of the vacuole. *Spirogyra triformis*, a species with thin walls

[23] VON SCHRENK, HERMANN, assisted by HILL, REYNOLDS, Seasoning of timber. Bull. No. 41. Bureau of Forestry, U. S. Dept. of Agric. pp. 48. *pls. 28. figs. 16.* 1903.

[24] GRAVES, H. S. and FISHER, R. T., The woodlot: a handbook for owners of woodlands in southern New England. Bull. No. 42. Bureau of Forestry, U. S. Dept. of Agric. pp. 89. *pl. 4. fig. 30.* 1903.

[25] VON SCHRENK, HERMANN, The "bluing" and the "red rot" of the western yellow pine, with special reference to the Black Hills forest reserve. Bull. No. 36. Bureau of Plant Industry. U. S. Dept. of Agric. pp. 40. *pls. 14.* 1903.

[26] HERTY, C. H., A new method of turpentine orcharding. Bull. No. 40. Bureau of Forestry, U. S. Dept. of Agric. pp. 43. *pls. 15. figs. 5.* 1903.

[27] WISSELINGH, C. VAN, Untersuchungen über Spirogyra. Vierter Beitrag zur Kenntniss der Karyokinese. Bot. Zeit. **60**: 115–138. *pl. 5.* 1902.

and loose, delicate chromatophores, was chosen for study. Material was fixed in Flemming's solution and afterward treated with a strong solution of chromic acid (40 per cent.), which dissolved successively the cytoplasm, karyoplasm and nucleolus, but did not dissolve the spindle fibers. Sections do not seem to have been used.

During the earlier stages of karyokinesis the nuclear membrane is entirely resorbed. The spindle is derived from the granular cytoplasm about the nucleus and consists of but one kind of fibers, the two different lengths of fibers and the two opposite groups described by Strasburger for *Spirogyra polytaeniata* not appearing in *S. triformis*. The spindle fibers do not grow through the nuclear membrane as described by Strasburger. The spindle is at first multipolar, but becomes bipolar. There is no diminution in the number of spindle fibers during karyokinesis, but after karyokinesis the spindle fibers become resolved into cytoplasm. The spindle fibers resist the action of chloral hydrate and so are easily distinguished from cytoplasmic strands. The walls of the vacuoles are also made visible by chloral hydrate. During karyokinesis the walls of the vacuoles with some cell sap press between the spindle fibers and appear within the spindle. Between the two halves of the nuclear plate a number of plasma strands are formed inclosing the spindle fibers, but there is no persistent, closed connecting tube as described by Strasburger for *S. polytaeniata*.—CHARLES J. CHAMBERLAIN.

A NUMBER of fossils, brought together by the late Sir William Dawson, have been described by Penhallow.[28] The first lot are from the Lower Cretaceous of Queen Charlotte islands, and the Upper Cretaceous of Port McNeil, Vancouver island. Several ferns are described, among them a new species, *Osmundites skidegatensis*, from Skidegate Inlet, Queen Charlotte islands, which is referred to at length in connection with a fuller subsequent description. Of gymnosperms there are species of Cycadites, Zamites, Ginkgo, and Sequoia. In *Sequoia langsdorfii* (Brongn.) Heer, the wood is described for the first time, although the foliage and fruit have long been known. The wood is of special interest because like that of *S. sempervirens*, the living species which so closely resembles *S. langsdorfii*, otherwise, it contains resin-canals such as are in general confined to the woody tissues of the Abietineae. The second lot of material is from the early Eocene of Blind Man river, N. W. T. of Canada, and includes a number of ferns, an Equisetum, and several gymnosperms. Several monocotyledonous and dicotyledonous species are also described and figured.

In another paper[29] Penhallow gives a fuller description of the fossil *Osmundites skidegatensis*, mentioned in the article referred to above. The

[28] PENHALLOW, D. P., Notes on Cretaceous and Tertiary plants of Canada. Trans. Roy. Soc. Canada II. 8:31–91. 1902.

[29] PENHALLOW, D. P., Osmundites skidegatensis. Trans. Roy. Soc. Canada II. 8:3–30. 1902.

account is based on the study of material collected by Dr. F. C. Newcombe from Alliford Bay, Skidegate Inlet, Queen Charlotte islands, and is illustrated by a number of photographs and photomicrographs, which testify to the admirable preservation of the fossil. The author concludes that the fossil represents a plant of the general habit of *Osmunda regalis*, but is much larger than any of the species of that genus found in North America. Internally it resembles Osmunda on the one hand and Todea on the other; but the resemblance seemed on the whole to be closer to Osmunda than Todea, so the fossil is included by the author in the genus Osmundites.— E. C. JEFFREY.

HABERLANDT sums up the present data of the statolith theory of geotropic preception,[30] prefacing his paper with a short historical account of the development of the same theory for animals. He answers certain objections which have been raised and contributes some new support to the theory, which now seems reasonably established for a considerable number of plants. Starch-bearing cells of the root cap in roots and of the starch sheath in stems (which is present in the majority of phanerogams, although Fischer, investigating too old portions of the stem, found it often wanting) are the preceptive organs, except in certain cases, where the geotropism is limited to the nodes, or where sharply differentiated groups of cells with movable starch grains replace the absent starch sheath. The preceptive apparatus is found to have degenerated in stems which have lost their geotropic sensitiveness, and to be lacking in organs which show no reaction to gravity. In general the root caps of apogeotropic climbing roots either contain no starch grains or non-motile ones. In orthotropous organs the protoplasmic membranes next the lower and upper transverse walls of the preceptive cells are not sensitive; only the membranes of the tangential longitudinal walls are irritable, and especially that of the outer wall in apogeotropic organs and that of the inner wall in positively geotropic organs. Whether both tangential walls of the same cell are sensitive is uncertain. In the nodes of grasses there is no ground for admitting this. The protoplasmic membranes on the radial walls are probably not sensitive. Any process which removes the starch from the starch sheath at the same time stops geotropic response, which, however, may begin again when the starch is regenerated. Czapek's demonstration of this in roots, from which starch disappeared when they were inclosed in plaster casts, is now supplemented by Haberlandt's experiments in removing starch by subjecting plants to low temperatures and then bringing the protoplasm into a condition of sensitiveness by raising the temperature. Until some hours have elapsed and starch grains have begun to appear, the geotropic sensitiveness does not manifest itself. Further experiments show that the action of gravity as a stimulus rests upon the static pressure of solid bodies. Further-

[30] HABERLANDT, G., Zur Statolithentheorie des Geotropismus. Jahrb. Wiss. Bot. **38**: 447–500. *fig. 3*. 1902.

more the time occupied by the fall of the starch grains through the cell fluids to the new position, which may be designated as the migration time, is shown to be usually less than half the presentation time. The migration time may be diminished by repeated mechanical jarring, in which case the presentation time is correspondingly diminished. It seems probable to the reviewer that subjecting plants to centrifugal action might reduce the migration time to a minimum and so demonstrate more clearly this relation.—C. R. B.

THE SEXUAL ORGANS and the development of the ascocarp of Monascus are described by Barker[31] in a paper of especial interest in relation to the problems connected with coenogametes among the Phycomycetes and Ascomycetes. A filament develops terminally an antheridium. Immediately below this cell the ascogonium is formed, whose growth pushes the antheridium to one side. Both sexual organs are multinucleate (coenogametes). They fuse by means of a small process put forth from the antheridium. After fertilization the ascogonium becomes divided by a cross wall, the anterior small cell remaining in connection with the antheridium, and the posterior, named the "central cell," developing the ascocarp.

After fertilization the central cell becomes invested by a growth of hyphae from below. The central cell now increases greatly in size, and the next change is the development of ascogenous hyphae in a little depression at one side of the central cell. The ascogenous hyphae gradually fill the interior of the ascocarp, eventually forming small eight-spored asci. The central cell plays a curious part in the later developments of the ascocarp. The growth of the ascogenous filaments so presses upon it as to force its wall inward, giving it the shape of a bowl. The ascogenous hyphae thus appear as an internal development, but their origin is plainly external. Later the contents of the central cell disappear, and its walls become cutinized, so that they actually form a hollow sphere around the ascogenous hyphae. Since the latter break down with the ripening of the spores, the mature ascocarp has the appearance of a simple sporangiumlike structure, which it is not.

Barker regards Monascus as a very lowly ascomycete, with relationships rather nearer to the Gymnoascales than to any other group. A number of points in his general discussion are treated in a note that follows my paper on Oogenesis in Saprolegnia.[32]—B. M. DAVIS.

[31] BARKER, B. T. P., The morphology and development of the ascocarp in Monascus. Ann. Bot. **17**: 167–236. *pls. 12, 13*. 1903.

[32] BOT. GAZ. **35**: 344. 1903.

NEWS.

DR. M. WESTERMAIER, professor of botany in the University of Freiburg, died on May 1.

DR. J. M. GREENMAN has been promoted to an instructorship in botany at Harvard University.

DR. JOSEPH E. KIRKWOOD, instructor in botany in Syracuse University, has been promoted to an associate professorship.

DR. C. ARTHUR HOLLICK will spend the summer in Alaska in paleobotanical investigations under the auspices of the U. S. Geological Survey.

AT THE June convocation the University of Chicago conferred the degree Ph.D. upon three candidates in botany, Harry N. Whitford, George M. Holferty, and John F. Garber.

DR. RAYMOND H. POND has been appointed professor of botany and pharmacognosy and director of the microscopical laboratories of the School of Pharmacy of Northwestern University.

M. FR. CRÉPIN, the director of the Royal Botanical Garden at Brussels, died April 30, at the age of seventy-two. He has been incapacitated for more than a year by illness. M. Th. Durand, the curator of the herbarium, has been appointed director.

THE WORK on *Pteridophyta* and *Spermatophyta* of Southern California, by Samuel B. Parish, which the Southern California Academy of Sciences proposed two years ago to publish as volume II of its Proceedings if a sufficient number of subscribers could be obtained, will not be published on account of lack of support for the undertaking.

DR. GUSTAV RADDE, imperial councilor and director of the Caucasian Museum, died recently at Tiflis at the age of seventy-one. He has been widely known as a student of the oriental flora. One of his last important works was *Grundzüge der Pflanzenverbreitung in den Kaukasusländern*, reviewed in this journal in April 1902.

ON APRIL 10, at the age of seventy-five, the venerable mycologist, Dr. Andreas Allescher, died suddenly of apoplexy at Munich. On retiring from active teaching in the Königl. Kreis-Lehrerinnen-Seminar he devoted the last five years of his life to the elaboration of the Fungi Imperfecti for Rabenhorst's *Kryptogamen-Flora*, a task which happily he completed before his death.

THE FORMAL OPENING of the new Lake Laboratory building of the Ohio State University, recently erected at Cedar Point, Sandusky, Ohio, took place Thursday, July 2, 1903. Addresses were given by Professor C. J.

Herrick, of Denison University, President of the Ohio Academy of Sciences; by members of the Board of Trustees and of the Faculty of the University; and by Professor Herbert Osborn, Director of the laboratory.

SCIENCE announces that Professor F. E. Lloyd, of Teachers College, Columbia University, left June 13, by the steamer "Caribee," for the island of Dominica, where, in the company of Mrs. Lloyd, he will spend the summer in the study of the flora. The expedition is under the auspices of the New York Botanical Garden, and the systematic collections will become a part of the garden herbarium. Professor Lloyd has received a grant of $200 from the Esther Herrman research fund of the Scientific Alliance of New York, to aid him in the collection of tropical Rubiaceae to be used in the furtherance of his researches in the embryology of that order.

IN APRIL 1903 appeared volume 1, number 1, of a monthly quarto review, entitled *Flora and Sylva*. The aim of this periodical is to illustrate in color and by good engravings new, rare, or valuable herbaceous plants, trees, and shrubs, fitted for the English climate, and to show appropriate and picturesque planting of grounds and garden design. The typography and paper are sumptuous; the colored plates, two in this number, are well executed chromolithographs. The illustrations in black are apparently wood engravings, the character of the paper preventing the use of half-tones. In this number articles on the hardy bamboos in England, on new daffodils, on the genus Magnolia, and a revision of the genus Calochortus, with shorter articles on a variety of subjects indicate the general scope of the journal. The editor is Mr. W. Robinson, the author of *The English flower garden*. *Flora and Sylva* promises to be a worthy addition to the horticultural literature of our day. No yearly subscription price is indicated; but the single number is marked "price half-a-crown."

THE REPORT of the officers of the New York Botanical Garden for 1902 shows that the number of herbaceous species grown in the Garden is about 3000. Grading operations and making of paths have still interfered with the extension of the planting of shrubs and trees, but the fruticetum contains over 530 species, the salicetum about 50 species, the arboretum about 300 species, and the viticetum about 60 species. A great increase has been made in the collections of plants cultivated under glass, which now number nearly 6000 species. The approach to the museum building and the public conservatory were completed during the year. The library has increased by nearly 2000 volumes and now consists of about 13,000 bound volumes. 67,000 specimens have been recived for the museum and herbarium. Forty-three students, including graduates of thirty-one different colleges and universities have been granted the privileges of the museum, library, and laboratories during the year, in addition to numerous visiting investigators from other institutions. Many explorations have been carried out by members of the staff, to which over $4000 has been devoted. The report is an interesting account of the progress of this great institution.

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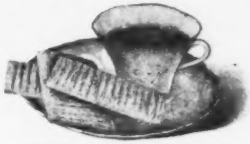

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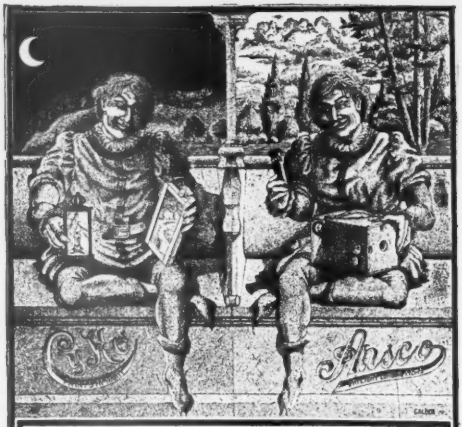

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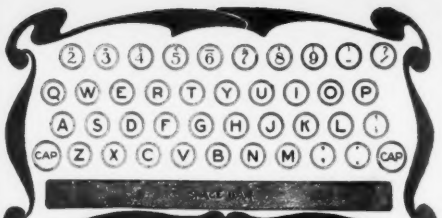

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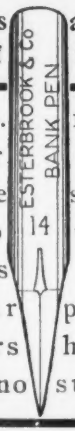

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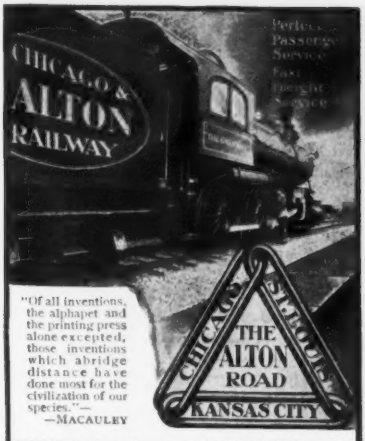

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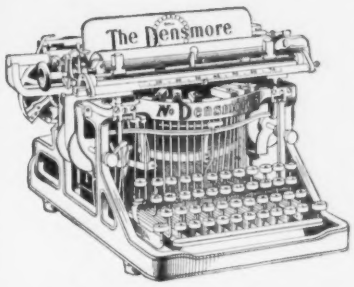

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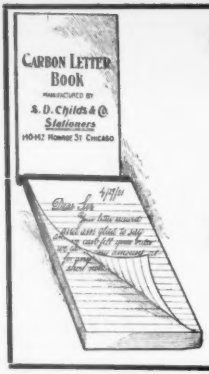

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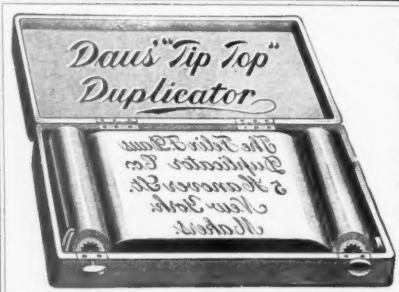

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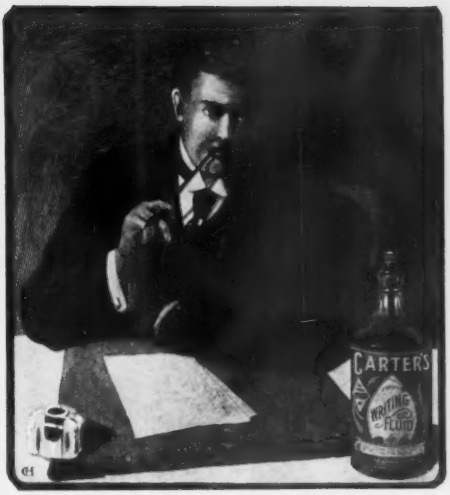

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